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SUGAR PINE

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IMPORTANCE OF SUGAR PINE.

Sugar pine (*Pinus lambertiana* Dougl.) was first recognized by David Douglas, of the London Horticultural Society, on the headwaters of the Umpqua River in Oregon, October 26, 1826. The tree was given the specific name *lambertiana* in honor of Douglas's friend Aylmer Bourke Lambert, a founder and vice president of the Linnean Society of London and the author of a prominent work on pines.

Sugar pine is the most valuable commercial timber tree on the Pacific coast, and its relative value among all the conifers of the world is very high. This is attributable partly to the characteristic straightness and unusual clear length of the trees and partly to the excellent physical qualities of the wood, which adapt it admirably to high-class uses in manufacture and trade.

Commercially, sugar pine may be considered, like the redwood, as essentially a California tree. Although it occurs in southern Oregon and in Lower California, it is relatively unimportant in both of these regions. The total stand in Oregon is estimated at approximately 3 billion

Note.—This bulletin describes the sugar pine, its growth, range, and uses in the form of lumber, and is of interest to foresters and wood users generally.

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feet, about equally divided between private and Government ownership. No reliable figures are available for Lower California, but the amount there is known to be small. Within California the best available estimates indicate a stand of 39 billion feet, board measure, about 24 billion on private lands and the remainder in Government ownership within the National Forests. Of the three most valuable widely distributed conifers within the State of California—redwood, yellow pine, and sugar pine—though the sugar pine ranks third in volume of stand, it is undoubtedly first in value of product.

GEOGRAPHICAL AND COMMERCIAL RANGE.

The geographical range of sugar pine extends from the valley of the Santiam River, in the Cascade Range, in Marion County, Oreg., through the Sierra and Coast Ranges of California to Mount San Pedro, in the peninsula of Lower California (Pl. I). Commercially, however, the species is of importance only from Douglas County, Oreg., to Kern County in the California Sierras, and Glenn County in the California Coast Range. The largest trees and heaviest stands within this area are found from Tulare to Eldorado Counties, Cal., along the west slope of the Sierras. Nearly three-fourths of the total stand is found in the Sierra Nevadas of California and the bulk of the remainder within that portion of the Coast Range which lies north of San Francisco. Over one-half of the total is distributed throughout the central Sierra region. It is seldom found in commercial stands on the east side of this range south of Plumas County.

ALTITUDE AND CLIMATE.

The altitudinal range of merchantable stands of sugar pine extends from 3,000 to 6,000 feet in the northern Sierras and from 5,000 to 9,000 in the southern Sierras, the southern coast range, and the Sierra Madres. A few trees have been reported in the redwoods near Cazadero, Sonoma County, Cal., at an elevation as low as 600 feet. The extreme upper limit of the botanical range occurs on Mount San Pedro, in Lower California, where the species has been reported at 11,000 feet. All gradations between these altitudes occur as the latitude changes.

In the sugar-pine belt the summers are hot and dry and the winters moderately cold. Most of the stands are found between the annual isotherms 44° and 60° F. Sugar pine occurs, however, in northern California, where the mean annual temperature is as low as 40°, and in the southern part of the State, where it is as high as 70° F. It endures average minimum monthly temperatures of 20° and average maximum monthly temperatures of 97° F.

Sugar pine is quite dependent upon atmospheric moisture. This characteristic probably accounts, in large measure, for its limited

occurrence and poor form on the eastern slope of the Sierra Nevada. The best commercial forests occur where there is an annual precipitation of 40 inches or more, although the species is found between precipitation limits of from 20 to 80 inches. Where the rainfall is below 30 inches, however, the trees are scattered and scrubby in form. The average snowfall in the sugar-pine belt is about 8 feet, with a range of from 3 to 20 feet.

HABIT AND ROOT SYSTEM.

Mature sugar pines have a striking individuality which enables one to indentify them at considerable distances. They generally rise above associated species and send out long, straight branches at right angles to the main stem.

The bole of sugar pine is sturdy, straight, and symmetrical. The taper is quite marked in young trees, but decreases from the fiftieth year until at maturity the trunk is well rounded out and the taper is very slight, except in the stump section. The tops of very old trees are often broken or flat, and the branches are irregular and have the appearance of being sparsely clothed with leaves. Young trees are symmetrical and branch regularly.

Seedlings have a well-developed taproot. This does not keep pace with the general development of the tree, however, and in later years the lateral root system is far more important, sometimes spreading over a radius of 40 feet and rendering the tree very resistant to wind.

BARK, LEAVES, FLOWERS, AND SEED.

The rich purple-brown or cinnamon-red bark of this tree is a distinguishing characteristic. In trees of above middle age it is deeply and irregularly divided into long, thick, platelike ridges. The bark of young trees is thin, quite smooth, and of a grayish color.

The foliage is dark green and composed of rigid needles from $2\frac{1}{2}$ to 4 inches in length, occurring in clusters of 5, except on seedlings, which bear clusters of 12 to 15 seed leaves.

During the spring flowering season the eye is attracted by the conspicuous light-yellow male flowers, oblong in shape, and from $\frac{1}{2}$ to 1 inch in length. The female flowers are of a less attractive pale green color, borne terminally on the branches in groups of two or more.

The cones of sugar pine are unique and serve to identify the species absolutely, mainly because of their great length, which averages from 13 to 18 inches and not uncommonly reaches 23 inches. They mature in late August of the second year, and are then from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter when closed, with blunt scales, slightly thickened at the tip. They are suspended on stalks at the very tips of the long branches, and when filled with their plump, blackish-brown seeds, from one-quarter to one-half inch in length, their weight imparts a

graceful downward sweep to the limb. Even in this position they can not escape the squirrels that depend on the rich-flavored seed for a winter food supply and cut large numbers before maturity.

SIZE AND LONGEVITY.

Sugar pine attains a greater size than yellow pine, white fir, incense cedar, or any of its associates, except the huge Sequoias of the Sierras, which tower far above it in the scattered localities where the two species occur together. Its average maximum height is 175 feet and the corresponding diameter 4½ feet. The maximum height reached is 240 feet and the maximum diameter 11 feet, measured outside the bark at 4½ feet above the ground. The average number of logs per thousand feet board measure, ascertained from sales of National Forest stumpage, varies from 4 in unfavorable situations to 1.5 in the best localities. This species attains an age of 500 years, but rarely more than that.

SUSCEPTIBILITY TO INJURY AND DISEASE.

Various injuries tend to shorten the life of sugar pine, but none result in the immediate death of a high percentage of mature stands except those caused by destructive insects.

FIRE.

Repeated fires cause butt scars or "cat faces," and thus weaken the tree mechanically, retard growth, and bring about conditions favorable to disease. Such scars also decrease the value of butt logs. Seedlings, saplings, and poles are destroyed in large numbers, but very few trees over 12 inches in diameter at breast height are killed, except on steep slopes during very high winds.

LIGHTNING, WIND, FROST, AND SNOW.

Sugar pine undoubtedly is injured more frequently by lightning than its associated species, yellow pine, fir, and incense cedar, because of its greater height and occurrence at relatively high elevations, where such storms are common; but because of the brief season during which lightning storms are prevalent, and their local character, the aggregate amount of damage wrought is not serious. Insects almost invariably attack lightning-damaged trees and complete the destruction, when the wound in itself would not prove fatal.

The strong, widespreading, lateral root system and the thick, sturdy bole of this tree resist winds of extraordinary velocity. Sometimes weakened trees in exposed situations yield to exceptionally severe storms. Large trees are subject to a mechanical defect known as windshake, the result of stresses in the butt section caused by severe wind in conjunction with low temperature. Circular seams are opened up and the value of the trees for lumber is lowered.

Since extremely low temperatures do not occur very often in the sugar pine belt, frost injuries are infrequent. Sapling and pole stands are occasionally injured by the wet snows of early winter, but sugar pine suffers less than yellow pine.

Breakage caused by lightning, winds, or wet snow is serious, not so much in itself, as because it opens the way to attack by insects. Not infrequently such damage gives rise to epidemic insect infestations.

STOCK, RODENTS, AND BIRDS.

Under regulated grazing the damage to young trees by cattle and horses is almost negligible. Sheep and goats, particularly goats, however, do appreciable damage by tramping down and nipping the leaders of young seedlings and saplings. Such stock should not be close-herded on areas of promising young forest, and should be moved frequently. They should be excluded from cut-over areas until reproduction is well started.

Each year the red or Douglas squirrel and the gray squirrel cut large quantities of cones, often while still unripe, and consume or store the edible seed. Other smaller rodents, as well as quail and jays, relish it also. The gray squirrel is so destructive to the seed of this species as to cast doubt upon the wisdom of according him the protection of the game laws in heavily forested counties. Wood rats and rabbits are destructive in young sugar pine plantations, sometimes cutting back every tree to the surface of the ground.

DISEASES.[1]

Sugar pine is without doubt one of the healthiest of our coniferous trees. Even the younger parts, such as the twigs and needles, are rarely attacked by the ordinary enemies of associated tree species, such as mistletoe (*Razoumofskya cryptopoda*), which frequently causes the formation of heavy witches' brooms and gnarls the branches of the yellow, Jeffrey, and lodgepole pine. A small bluish witches' broom, caused either by a parasitic fungus, or more probably, a mite, and resembling a spiny ball from 1 inch to 20 inches in diameter, is fairly common throughout the Sierra Nevadas. An unidentified species of *Peridermium*, probably *P. harknessii*, is also occasionally found on sugar pine. The damage caused by these diseases is, however, insignificant. The wood-destroying fungi cause more damage, but the loss is rarely more than 3 per cent of the gross board measure content of the stand. The fungi almost invariably attack the heartwood of the older and more valuable trees; therefore, though the number of trees killed is small, the monetary loss through their work is appreciable. *Trametes pini* and *Fomes laricis* are by far the most destructive of the wood-destroying fungi which attack sugar pine. Sporophores of *Fomes pinicola* have

[1] Inquiries regarding diseases of forest trees should be addressed to the Bureau of Plant Industry, U. S. Department of Agriculture.

been found on mature green trees. *Polyporus volvatus* is common on dead trees. The damage done by the former is minor, and that wrought by the latter is of no importance.

INSECTS.[1]

Insects are responsible for the destruction of large quantities of merchantable sugar pine timber. In the northern portion of the tree's range bark beetles of the genus Dendroctonus are very destructive; in the southern portions their work is supplemented by that of the flat-head beetles of the family Buprestidæ. The annual loss of sugar-pine timber from beetles is roughly estimated at not less than one-half of 1 per cent of the merchantable stand. In certain localities epidemics of insects have resulted in the loss of from 5 to 10 per cent.

While the roots, limbs, twigs, foliage, cones, and seed of this tree all have insect enemies, a tree is never known to have been destroyed except by those which attack the trunk. The mountain pine beetle (*Dendroctonus monticolæ*, Hopk.) is by far the most serious enemy. The adult beetles bore through the cork bark and deposit their eggs in the living inner bark, which is an important part of the circulatory system of the tree. Upon hatching, the larvæ or grubs completely girdle the tree by consuming the tissues in narrow channels or galleries extending around its circumference. The presence of these beetles in a tree is denoted first by reddish "pitch-tubes" or deposits of resin and wood dust caused by the beetles' entrance and later by the yellowing of the crown when the tree begins to feel the effect of the girdling.

The red turpentine beetle (*Dendroctonus valens* Le Conte) attacks the base and roots of the tree. Generally its work is of a secondary nature, but occasionally, when very numerous, it is the primary cause of death. According to the Bureau of Entomology it is also one of the primary causes of basal fire wounds.[2]

From the Kern River southward a species of flat-head borer (*Melanophila gentilis* Le Conte) causes a considerable loss. The five-spined engraver beetle (*Ips confusus* Le Conte) is occasionally responsible for the killing outright of young sugar pines in the sapling or pole stage of growth and for the dead tops of many more mature trees. Other less important insects do minor damage to various parts of the tree. Among these are a weevil (*Pissodes yosemitei* Hopk.), which injures the bark and young saplings; a saw-fly (*Lophyrus* sp.), which damages the foliage, and the sugar pine cone beetle (*Conophthorus lambertianæ* Hopk.), which attacks the stems of the young cones as well as the cones themselves and causes the latter to fall before maturity, thus preventing the maturing of the seed.

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[1] Inquiries in regard to insects affecting forest trees should be addressed to the Branch of Forest Insects, Bureau of Entomology, U. S. Department of Agriculture.

[2] See pages 153–165 of Bureau of Entomology Bulletin 83, Part I, "Practical information on the scolytid beetles of North American forests. Barkbeetles of the genus Dendroctonus," by A. D. Hopkins.

Since slash from cuttings or natural damage, such as windfall or snowbreak, furnishes excellent breeding ground for destructive insects and materially increases the fire danger, such refuse should be disposed of by fire whenever possible before the spring following the cutting or other occurrence.

These insects are normally kept in check by woodpeckers, certain predaceous and parasitic insects, and certain fungi. When, however, an infestation by the mountain-pine beetle commences to increase rapidly it can be controlled only by peeling the infested portions of the principal groups of affected trees during the fall or early spring before the beetles emerge. It is usually necessary as a precaution against fire to dispose of the resulting slash by burning at a safe time. These control measures, as conducted by the Forest Service, have cost from $2.50 to $5 per tree, according to conditions. For each tree cut in control work it seems evident from statistics that one is saved. Since an average sugar pine tree is worth at least $15 on the stump, the saving is worth making.[1]

SILVICAL REQUIREMENTS.

MOISTURE AND SOIL.

The most essential requisite for the rapid development of sugar pine throughout all stages of its life history, but particularly during the seedling and sapling periods, is moisture in both soil and air. Lacking this, it becomes stunted, malformed, and useless as a timber tree. It is generally found on cool northerly slopes and in ravines where the humidity is highest.

Though sugar pine occurs on a variety of soils, from glacial drift and volcanic ash to deep, loose sands and clays, its maximum development is reached only on comparatively moist, loose, deep sandy loam. Its presence is unusual on hot, dry slopes as well as on poorly drained wet soils. The chemical composition of the soil apparently has but little bearing on its distribution.

The relative soil and moisture requirements of this species are indicated by the following list, in which the more exacting species precede the less exacting:

Soil.	Moisture.
Douglas fir.	Red fir.
White fir.	SUGAR PINE.
Red fir.	Douglas fir.
SUGAR PINE.	White fir.
Incense cedar.	Incense cedar.
Yellow pine.	Yellow pine.
Jeffrey pine.	Jeffrey pine.

[1] For further details regarding control measures, see pages 87–89 of Bureau of Entomology Bulletin 83, Part I.

LIGHT.

Sugar pine demands a very great amount of light, except in early youth, and always just as much light as will not interfere seriously with the moisture conditions. The maintaining of the balance between light and moisture offers the hardest problem the forester has to solve in his attempts to increase the representation of this species in the forest mixture of the future. During the seedling and sapling stages, on account of persistent demands for moisture, sugar pine must have at least partial shade. As it gets older, however, it demands more and more light up to the point where a further addition of light would do harm by decreasing too much the amount of moisture in the soil and air.

The relative demands of the different species for light vary, quite naturally, according to geographical and altitudinal location. It may be worth while, nevertheless, to show how sugar pine and its associates rank in this respect where sugar pine is most flourishing. In the following list the trees are ranked in the order of their ability to endure shade:

Western yew	*Taxus brevifolia.*
California nutmeg	*Tumion californicum.*
Mountain or black hemlock	*Tsuga mertensiana.*
Incense cedar	*Libocedrus decurrens.*
White fir	*Abies concolor.*
Sugar Pine	*Pinus lambertiana.*
Red fir	*Abies magnifica.*
Douglas fir	*Pseudotsuga taxifolia.*
Western white pine	*Pinus monticola.*
Jeffrey pine	*Pinus jeffreyi.*
Western yellow pine	*Pinus ponderosa.*
Juniper	*Juniperus californica.*
Lodgepole pine	*Pinus contorta.*
Knobcone pine	*Pinus attenuata.*
Digger pine	*Pinus sabiniana.*

REPRODUCTION.

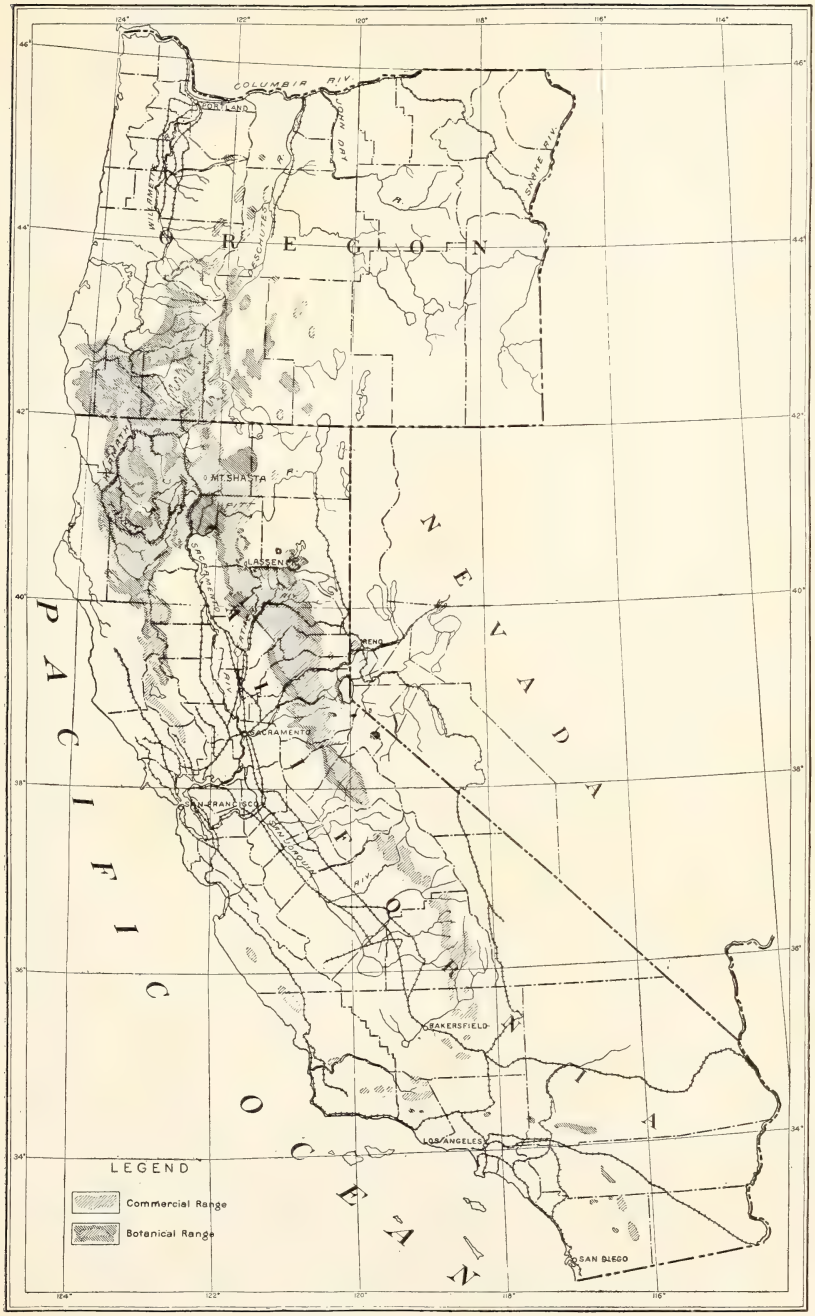
Except under the very best soil, moisture, and shade conditions, there is a noticeable scarcity of sugar-pine reproduction in the present forest, even where this species makes up as much as 25 per cent of the merchantable stand. This scarcity is attributable to the following causes:

(1) The seed is very conspicuous and edible. Large quantities are therefore consumed by birds and rodents.

(2) The proportion of the seed that germinates is small.

(3) The moisture requirements for germination are exacting.

(4) The seedlings are very susceptible to injury from fire, drought, or severe sunlight.



DISTRIBUTION OF SUGAR PINE.

F—1-05

MATURE SUGAR PINE TREE, SHOWING BOLE, BRANCHING HABIT, AND REPRESENTATIVE CLEAR LENGTH, PLUMAS COUNTY, CAL.

F—2—D5

GROUP OF THRIFTY YOUNG SUGAR PINE, YELLOW PINE, WHITE FIR, AND INCENSE CEDAR SAPLINGS AND POLES, SOUTHERN SIERRA REGION, CALIFORNIA.

F—18252A

CHARACTERISTIC GROUP OF SUGAR PINE TREES IN A GOOD LOCALITY, SUGAR PINE-YELLOW PINE TYPE, SHASTA COUNTY, CAL.

While there is a fair crop of sugar-pine seed each fall in some portion of its range, good seed years throughout occur only at intervals of from three to five years. Cones are occasionally borne by trees from 40 to 50 years old, but the best and most abundant seed is obtained from 125 to 175 year-old trees. The ability to produce seed in large quantities is possessed by huge trees that are long past maturity and deteriorating.

A bushel of cones (about 20, each containing approximately 200 seeds) produces 2 pounds of seed, of which from 20 to 50 per cent will germinate. Germination is peculiarly slow, often continuing throughout two full seasons in seed beds. This makes the species difficult to handle in the nursery.

The seed is disseminated principally by wind, which generally does not transport it over 150 yards, because of its large size and relatively small wings.

On the drier and more exposed situations sugar-pine reproduction can not compete with yellow pine or incense cedar. On humus soils in moist protected spots it succeeds fairly well. Its chief competitor here is the white fir, which has the advantage of bearing abundant light seed, which is not attractive to rodents. The ability of sugar-pine seedlings to endure shade enables them to contend successfully with brush on moist favorable sites. Sugar pine is much more susceptible to injury from ground fires than white fir, yellow pine, or incense cedar seedlings, and the absolute exclusion of fire is essential to the securing of a young stand of this species on cut-over areas.

FOREST TYPES.

Sugar pine frequently occurs in pure stands covering about an acre, but is never found on larger areas without other species in mixture. Yellow pine, incense cedar, white fir, and Douglas fir are its most common associates, followed by red fir and Jeffrey pine at higher elevations. Occasionally it mingles with western white pine, lodgepole pine, yew, whitebark pine, limber pine, knobcone pine, coulter pine, and at low elevations with various species of oak. These combinations, however, are only of botanical interest. Largely as a result of repeated fires, stands of sugar pine are generally rather open and contain considerable underbrush, composed of various species of ceanothus, manzanita, oaks, buckthorns, cherries, serviceberry, and chinquapin.

For descriptive purposes, stands containing sugar pine have been divided into the following cover types, based upon the number of trees of each species that are found in mixture.

SUGAR PINE-YELLOW PINE TYPE.

In the sugar pine-yellow pine type, sugar pine makes up over 15 per cent of the stand, its associates in the order of their commercial importance being yellow pine, white fir, Douglas fir, incense cedar, Jeffrey pine, and bigtree. This type generally occurs at an elevation of from 4,000 to 7,000 feet in the western central Sierra region of California. Sugar pine is at its best in this region and many large pine lumbering operations are located within it. The altitudinal limits of the type vary with change of latitude, being somewhat lower in the northern part of California and higher in the southern. Because of the exacting moisture requirements of sugar pine, the heaviest stands in this type are found in moist draws, or gulches, where the humidity is highest, and on north and east slopes. It is in the gulches that Douglas fir is most prominent. On the hotter, drier slopes, sugar pine is largely replaced by yellow pine and cedar.

SUGAR-PINE FIR TYPE.

The sugar pine-fir type has over 15 per cent sugar pine, Douglas fir and white fir in considerable quantities, and no yellow pine. It occurs in favorable moist, humid situations and is found principally in the northern portion of the Sierra Nevadas and Coast Ranges. This type covers a much smaller area than the sugar pine-yellow pine type and is relatively unimportant. To the south it merges into the yellow pine-sugar pine or fir type.

In addition to these two distinct cover types in which sugar pine is the key tree, it is found less well represented in the yellow pine, Jeffrey pine, fir, and red fir types. In short, wherever the annual precipitation is sufficient to meet its requirements and sufficient light is available, this tree may be found. As moisture conditions become less favorable it seeks sheltered localities, and as they improve it ventures into more exposed situations. The dense shade and fogs of the coast redwood and Douglas fir forests prevent it from becoming an important factor in the heavily forested belt west of the California coast range.

THE WOOD.

APPEARANCE AND STRUCTURE.

In external appearance the wood of sugar pine is strikingly similar to that of eastern white pine (*Pinus strobus*) and western white pine (*Pinus monticola*). The sapwood and heartwood are fairly well defined; the former is white or yellowish white, the latter a very light brown, sometimes tinged with red in old trees which are very resinous.

QUALITY.[1]

Sugar pine is moderately hard and heavy, moderately strong and stiff, poor in shock-resisting ability, moderately coarse but straight-

[1] The paragraphs dealing with markets and manufacture and the uses, quality, weight, strength, durability, and treatment of the wood were prepared by Carl A. Kupfer, forest examiner, Forest Service.

grained, and of smooth, rather fine texture. It is easily worked, takes a nail well without splitting, and when finished has a satiny luster. Among woods showing only slight shrinkage, swelling, and warping due to varying atmospheric conditions, sugar pine ranks with the best. Although resinous, it is comparatively free from noxious elements which impart contaminating flavors and odors.

WEIGHT, STRENGTH, SHRINKAGE, AND HARDNESS.

The following figures on weight, strength, shrinkage, and hardness of sugar pine are largely the result of tests conducted by the Forest Service on material from five representatives trees cut in Madera County, Cal. These tests were made at the Forest Products Laboratory, Madison, Wis., and the results are directly comparable with those obtained for the other commercial woods which have been studied. The test specimens used were small and clear, and for strength determinations were 2 by 2 inches in section. Bending specimens were cut 30 inches long; others were shorter, depending on the kind of test.

TABLE 1.—*Shipping weights, sugar pine lumber, per 1,000 feet board measure.*

2-inch dimension.		1-inch boards.		4-foot lath (per thousand).
Rough.	S1S1E.	Rough.	S1S or S2S.	
Pounds. 2,650	*Pounds.* 2,300	*Pounds.* 2,500	*Pounds.* 2,200	*Pounds.* 450

TABLE 2.—*Average mechanical properties of small, clear, green sticks of sugar pine, western yellow pine, white pine, and Douglas fir.*

Species.	Static bending.			Compression parallel to grain.	Compression perpendicular to grain.
	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Crushing strength.	Fiber stress at elastic limit.
	Lbs. per sq. in.	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Douglas fir (Pacific Northwest)	4,920	7,795	1,577	3,910	528
Sugar pine (California)	3,330	5,270	966	2,600	353
White pine (Wisconsin)	3,410	5,310	1,073	2,720	314
Western yellow pine (California)	3,180	5,180	1,111	2,420	326

TABLE 3.—*Shrinkage of small, clear pieces of sugar pine, western yellow pine, white pine, and Douglas fir from green to oven-dry condition.*

Species.	In volume.	Radial.	Tangential.
	Per cent.	*Per cent.*	*Per cent.*
Douglas fir (Pacific Northwest)	12.7	5.0	7.8
Sugar pine (California)	8.4	2.9	5.6
White pine (Wisconsin)	7.8	2.2	5.9
Western yellow pine (California)	11.5	4.3	7.3

TABLE 4.—*Hardness of small, clear, green sticks of sugar pine, western yellow pine, white pine, and Douglas fir.*

Species.	Surface.		
	End.	Radial.	Tangential.
	Load required to embed a 0.444-inch steel ball to one-half its diameter.		
	Pounds.	*Pounds.*	*Pounds.*
Douglas fir (Pacific Northwest)	511	457	490
Sugar pine (California)	334	307	342
White pine (Wisconsin)	304	294	299
Western yellow pine (California)	316	306	323

The specific gravity of the dry wood of sugar pine is 0.386. The weight of a cubic foot of oven-dry wood is 24.1 pounds. The weight of white pine (*P. strobus*) is 24.4 and of western yellow pine (*P. ponderosa*) 26.3 pounds. The green weights per cubic foot for the three species are: Sugar pine, 50.2 pounds; white pine, 39.5 pounds; western yellow pine, 48 to 53.1 pounds.

The shipping weights for sugar pine lumber of different sizes, accepted by manufacturers, are shown in Table 1. Table 2 shows the strength, Table 3 the shrinkage, and Table 4 the hardness of sugar pine and several other species.

DURABILITY.

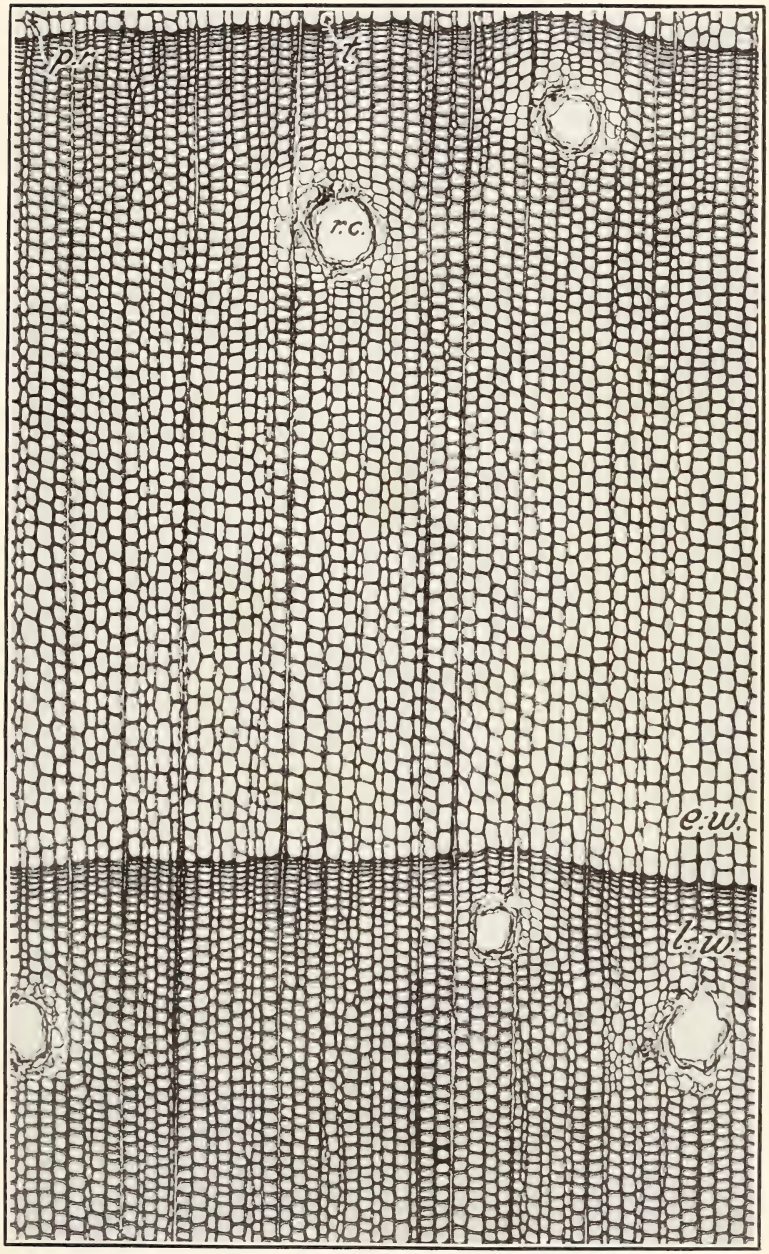
Early settlers found sugar pine more durable than the commoner western yellow pine and used a great deal in fence construction and building. In contact with the ground it lasts longer than most of the common Sierra species, but is not so durable as incense cedar or juniper. In the air, even where exposed to all kinds of weather, it shows great lasting properties.

TREATMENT.

So far as is known, no attempt has been made to increase the life of sugar pine by preservative treatment. Its value for other purposes is so great that very little of it is used in contact with the ground. Theoretically, the sapwood should receive preservatives very readily, but the heartwood, like that of white pine, is so close-grained as to resist absorption and penetration under ordinary methods of treatment. Applications of paint, oil, varnish, or shellac, or boiling in oils or paraffin, would doubtless increase its life by preventing the absorption of water.

LOGGING.

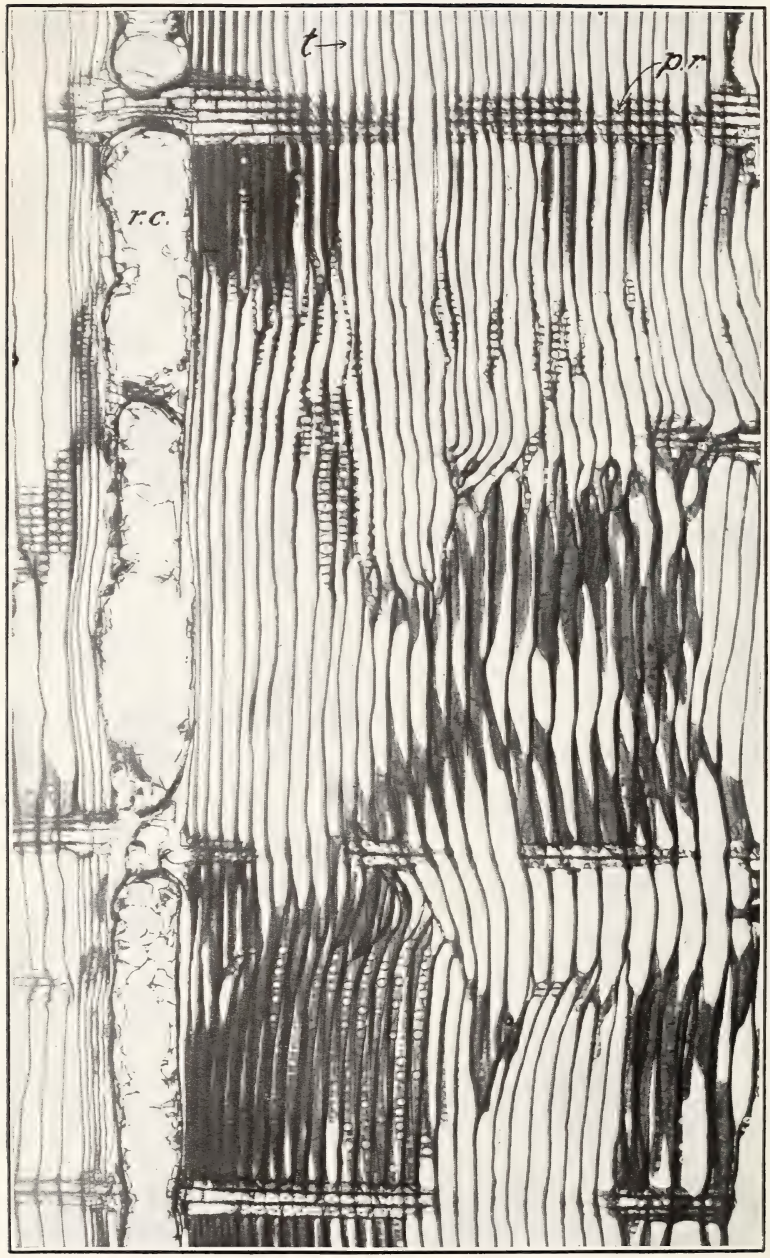
The process of logging sugar pine in a typical California operation consists of the following steps: Felling, bucking, yarding, chuting or "roading," loading, hauling to mill.



F—3—D5

TRANSVERSE SECTION OF THE WOOD OF SUGAR PINE MAGNIFIED 50 DIAMETERS.

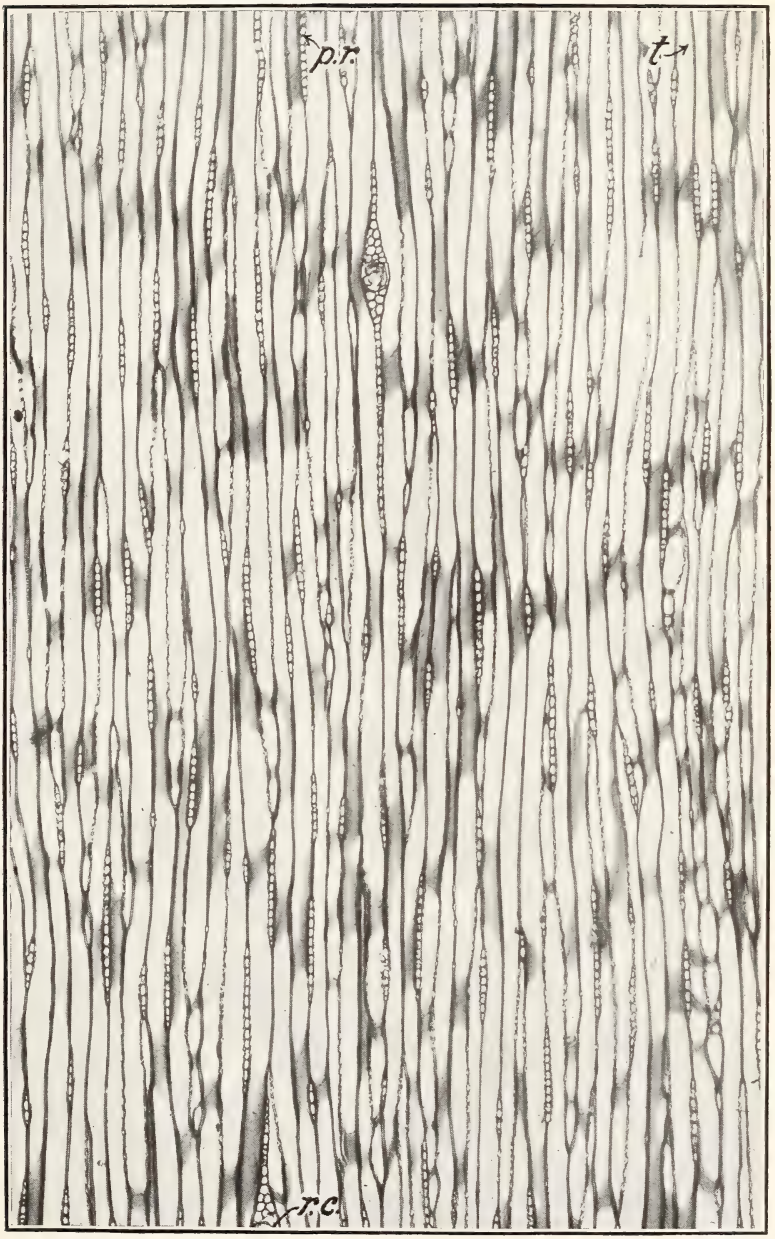
e. w., Early wood; *l. w.*, late wood; *t.*, tracheids; *p. r.*, pith rays; *r. c.*, resin canal.



F—4-D5

RADIAL SECTION OF THE WOOD OF SUGAR PINE MAGNIFIED 50 DIAMETERS.

t., Tracheids; *p. r.*, pith rays; *r. c.*, resin canal.



F—5—D5

TANGENTIAL SECTION OF THE WOOD OF SUGAR PINE MAGNIFIED 50 DIAMETERS.

t., Tracheids; *p. r.*, pith rays; *r. c.*, resin canal in pith ray.

The felling crew is generally made up of an undercutter, who decides which way the tree shall fall and notches it with an axe on that side, and two "fallers," who cut the tree down with a cross-cut saw. Such a crew usually fell from 55,000 to 60,000 feet per day. They are followed by the marker, who divides the tree into the proper log lengths, and the buckers, who cut it into logs. Working singly with cross-cut saws, the buckers average 9,000 to 10,000 feet daily.

The next step, yarding, consists in transporting the logs from the woods to the chutes or railroad landings. This is accomplished generally by means of steam donkey engines called "yarders," which operate strong wire cables reeled on drums. The largest machines can carry sufficient cable to bring in logs 2,000 feet away; 1,200 feet is an average pull, however. From 10 to 13 men are required in a yarding crew for handling from 25,000 to 40,000 feet of logs per day. Wherever possible, logging railroads are used and the yarding engines are located along these roads. Sometimes, however, when the logs reach the yarder they are placed in V-shaped log chutes and pulled to the mill or railroad by another usually larger, donkey engine known as the chute donkey, roader, or bull donkey.

At the mill the logs are generally placed in a pond for storage. From here they can be readily pulled into the mill for sawing.

The average cost per 1,000 feet of logging sugar pine and yellow pine is about $5.30, itemized as follows:

Felling and bucking	$0.65	Chute construction	$0.15
Yarding	1.80	Railroad	.50
Chuting (54 per cent of cut)	.35	Depreciation	.35
Loading	.25		5.30
Railroad haul	1.00		
Supervision	.25		

In the sugar-pine region various methods of logging are used. Small-mill operators can not make the heavy investments necessary for donkey engines, and they commonly yard logs to chutes by means of six-horse or eight-horse teams. The logs are hauled in the chutes in trains of 8 or 10 by similar teams. These horse chutes usually end at the mill. Other small outfits deliver the logs at the mill by means of eight-horse trucks, which are loaded by horses at landings in the woods. In the northern part of California many localities are so smooth that large operators find it an economy to yard logs by means of horses and overhead big wheels.

MILLING.

Two main types of mills are used, those in which circular saws do the cutting, and the larger, more modern mills, which employ band saws. Rotary mills usually saw lumber for the local market. While such mills require a smaller investment than band mills, their output is less, the cost of operation is higher, and the waste is greater. The

usual daily output of circular mills varies from 20,000 to 40,000 feet, while single band saws cut about 60,000 feet in a 10-hour shift. The double-band type is usually installed now by large operators. Such a mill running night and day, a practice frequently followed during good market conditions, manufactures from 225,000 to 250,000 feet of lumber each day, or from 40,000,000 to 50,000,000 feet each season.

The following cost items give a correct general idea of the expense of manufacturing sugar-pine lumber from the time logs reach the pond up to and including the loading of the finished lumber on cars for shipment.

Cost per 1,000 board feet.

Unloading logs in pond	$0.07
Milling	1.50
Maintenance	.50
Distribution and yard handling	.33
Piling	.40
Surfacing a part of stock and loading on cars	.90
	3.70

Sugar pine is cut in the following stock sizes: 1″, 1¼″, 1½″, 2″, 2½″, 3″, and 4″ in grades Nos. 1, 2, and 3 clear and Nos. 1 and 2 shop. Dimension stock, graded Nos. 1, 2, and 3 common, is cut 1″ and 2″, while box, which uses up nearly the entire output of common, is cut 1″ and 1½″. All grades above common are cut to surface, on two sides, full ⅞″, 1 7/16″ 1 3/16″, 1⅞″, 2 3/16″, 2⅞″, and 3⅞″. Slabs and other "waste" sometimes are used in the manufacture of 4-foot lath. Much of the sugar-pine lumber now being supplied to the markets east of the Sierras is in the form of shop lumber for general mill-work. Siding, ceiling, etc., are manufactured only incidentally to fill special orders, and can not be considered standard products of sugar-pine mills.

CUT.

Sugar pine was not exploited extensively until 1895, and no attempt to market it as a separate species was made until 1901. Exact figures showing the amount cut up to 1907 are not available, but, as nearly as can be ascertained, this amount ranged from 30,000,000 feet in 1902 to 90,000,000 feet in 1907. The mills cutting sugar pine and other species produced approximately 500,000,000 feet board measure, of all species, annually from 1909 to 1913. Sugar pine formed 22 per cent of this amount, or 110,000,000 feet. The cut in 1908 was somewhat less on account of the industrial depression. In 1913 the cut was close to 120,000,000 feet.

Probably a billion feet of sugar pine has been cut since 1901, or a little over 2 per cent of the total stand. The disturbances in the lumber market attendant upon the European war have probably decreased this scale of production temporarily. Large holders of pine

timber are, however, beginning to feel the pressure of interest charges, taxes, and other items of expense connected with carrying stumpage. Operations have recently started on a large scale on two such holdings, and there are indications that several more will follow within the next 5 years should market conditions improve with the closing of the war in Europe. The carrying charges on National Forest stumpage are borne by the United States, and a constantly increasing number of lumbermen are operating in Government timber. It is predicted that the annual cut of California pine will reach 650,000,000 feet by 1920. Of this amount 150,000,000 should be sugar pine.

Table 5 gives the number and type of the principal mills at present producing sugar-pine lumber, together with their average and total annual output of this species.

TABLE 5.

	Type of mill.			
	Double band.	Single band.	Circular.	Total.
Number of mills	10	8	15	33
Average annual output, feet, b. m.	8,008,000	2,500,000	704,000	11,212,000
Total annual output, feet, b. m.	80,080,000	20,002,000	10,561,000	110,643,000

GRADE PRODUCT OF SUGAR-PINE LOGS.

The average quality of sugar-pine timber is fairly well indicated by the results of a mill tally of 855 logs made during the summer of 1914 at about the middle of the range of this species from north to south. Farther south the quality is better, and farther north, poorer. The logs are divided into three grades: Grade I, or clear logs; Grade II, or shop logs; and Grade III, or rough, common logs. Both sound and defective logs were tallied. Grade I logs made up 22.7 per cent of the net log scale; Grade II, 42.8 per cent, and Grade III, 34.5 per cent.

Including both sound and defective logs, the quality of lumber within each log grade, by actual tally, is shown in Table 6.

TABLE 6.—*Lumber grade product of sugar pine within log grades.*

Grade of log.	1 and 2 clear.	3 clear.	C select.	Australian.	1 shop.	2 shop.	3 shop.	1 and 2 common.	3 common.	Box.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Grade I	33.6	9.3	0.2	0.5	19.3	11.0	2.6	1.0	.....	8.5
Grade II	4.2	2.6	.1	.1	15.9	22.3	7.7	37.9	0.4	8.8
Grade III	.9	.4	.....	.....	2.7	6.8	6.6	63.2	.....	19.4
All grades	9.4	3.3	.1	.2	11.9	14.2	6.2	41.9	.2	12.5

The proportion of each of the principal lumber grades produced from diameter classes of sound logs is given in Table 7. The diameter classes are based upon the small-end diameters of logs and are inclusive.

TABLE 7.—*Lumber grade product of sugar pine by log grades and log diameter classes.*

LOG GRADE I.

Diameter class logs.	1 and 2 clear.	3 clear.	1 shop.	2 shop.	3 shop.	1 and 2 common.	Box.
	Per ct.	*Per ct.*	*Per ct.*	*Per c*	*Per c*	*Per ct.*	*Per ct.*
25 to 28 inches	21	8	19	10	2	35	5
29 to 32 inches	23	8	20	11	2	31	5
33 to 36 inches	25	9	21	11	3	25	6
37 to 40 inches	27	10	22	11	3	21	6
41 to 44 inches	30	10	22	12	3	16	7
GRADE II.							
21 to 24 inches	3	2	10	18	6	57	4
25 to 28 inches	3	2	11	23	6	50	5
29 to 32 inches	3	2	13	25	6	44	6
33 to 36 inches	4	2	17	26	6	38	7
37 to 40 inches	6	4	20	24	6	33	7
41 to 44 inches	7	5	22	21	7	30	8
GRADE III.							
9 to 12 inches	.....	.....	.....	.....	.....	86	14
13 to 16 inches	.....	.....	.....	0.5	0.5	84	15
17 to 20 inches	0.1	.....	1	2	3	80	14.9
21 to 24 inches	0.2	0.1	2	7	8	68	14.7
25 to 28 inches	0.3	0.1	3	12	13	58	13.6
29 to 32 inches	0.4	0.2	4	15	17	50	13.4
33 to 36 inches	0.4	0.2	6	19	21	41	12.4

The same study gave figures on the overrun of the lumber tally over the log scale (Table 8). The mill was an efficient single band with standard equipment. The sawing practice was normal for the region, except that railroad ties were sawed from many of the top logs, which gave too high an overrun for Grade III logs.

TABLE 8.—*Overrun by log grades and log quality.*

	Sound logs.	Defective logs.	Sound and defective logs.
	Per cent of the log scale.		
Grade I	3.0	2.1	2.6
Grade II	6.3	4.6	5.9
Grade III	11.6	8.9	11.1
Total	7.8	4.6	7.0

VALUES AND GRADES OF LUMBER.

The value and amount of the higher grades of lumber obtained from a species measure its intrinsic commercial worth.

Sugar pine logs yield a higher percentage of wide, clear, high-grade lumber than yellow pine. This material commands a high price for special uses in the trades, which accounts for the lumberman's

CHUTE LOGGING WITH A DONKEY ENGINE, PLUMAS COUNTY, CAL.

F—95302

F—30927

TRAINLOAD OF PINE LOGS, SISKIYOU COUNTY, CAL.

decided preference for sugar pine timber. The choice material is derived from large, overmature trees. The smaller trees are on a par with yellow pine in value of product, and at the time of a second cutting the value of these two species will undoubtedly be nearly identical.

Table 9 shows the average percentage of the various grades produced from sugar pine and yellow pine in the best representative Sierra Nevada stands. In the very best stands sugar pine cuts out as high as 50 per cent upper-grade lumber (No. 2 shop and better).

TABLE 9.—*Average percentage of the various grades produced from sugar pine and yellow pine.*

Grade.[1]	Species.		Grade.[1]	Species.	
	Sugar pine.	Yellow pine.		Sugar pine.	Yellow pine.
No. 1 and clear	13.2	10.0	No. 3 shop	5.0	6.0
No. 3 clear	6.6	3.6	No. 1 and 2 common	22.0	25.0
C select		3.6	Box	23.0	27.0
No. 1 shop	11.0	9.0	No. 3 common	6.0	5.0
No. 2 shop	13.2	10.8	Total lowers	56.0	63.0
Total uppers	44.0	37.0			

[1] Sugar and yellow pine are graded under rules established by the California Sugar and White Pine Co., of San Francisco, Cal. (See Appendix, p. 40.)

Although market prices fluctuate considerably from year to year, they indicate comparative values. There was a strong rising market for California sugar pine from 1903 to 1907. The financial depression of 1907 produced a decided slump, which was followed by a partial recovery in 1909. From 1909 to 1912 prices were fairly constant, with a slight tendency to increase. In 1914 the general business depression and European war were severely felt in the pine market.

Table 10 shows concretely the general increase in the price of upper grades and a comparison between 1905 and 1912 prices.

TABLE 10.—*Net selling price of sugar and yellow pine lumber by grades, f. o. b. mill*

Grades.	Prices per 1,000 feet.		
	1905	1912	
	Sugar pine.	Sugar pine.	Yellow pine.
Nos. 1 and 2 clear	$43.00–$46.00	$50.00–$57.00	$37.75–$42.50
No. 3 clear	33.00– 38.00	38.00– 40.00	32.00– 34.00
C select		38.00– 40.00	31.00– 33.00
No. 1 shop	22.00– 28.00	30.70– 31.30	24.00– 26.50
No. 2 shop	15.00– 18.00	20.45– 22.00	15.50– 20.00
No. 3 shop		13.25– 15.00	13.00– 15.00
Nos. 1 and 2 common		14.75– 18.00	14.00– 18.00
Box		12.50– 13.50	12.00– 13.50
No 3 common		10.00– 12.00	3.10– 11.40

The "mill-run" value, which is the average of all prices obtained for the various grades manufactured, varies with the location of the mill and the quality of the timber. The greater the proportion of the lower grades produced, the lower is the average mill-run price. In appraisals of National Forest stumpage, the average mill-run prices of sugar pine shown in Table 11 were ascertained upon the basis of selling prices current during 1912.

TABLE 11.—*Mill-run values of sugar pine lumber.*

[Price per 1,000 feet.]

Locality.	Species.		Locality.	Species.	
	Sugar pine.	Yellow pine.		Sugar pine.	Yellow pine.
Siskiyou County	$21.00	$19.00	Plumas County	$23.00	$19.00
Upper Sacramento	21.00	19.00	Central San Joaquin	24.00	20.00
Lower Sacramento	24.10	19.80	Southern San Joaquin	23.45	19.65

DEPRECIATION OF SUGAR-PINE LUMBER DURING AIR SEASONING.

In the summer of 1914, the Forest Service carried on a study to determine the depreciation in grade of pine lumber during air seasoning. Depreciation during seasoning by this method is caused by checks, blue stain, brown stain, warping, splitting, and breakage in handling. The heaviest depreciation occurs in high-grade lumber (No. 2 shop and better). The amount of loss is determined largely by climatic conditions, method of piling, location of pile, length of ime in pile, and characteristics of species.

At lumber yards in the hot valley regions of California brown stain seems to cause one-third of the depreciation in grade.

Table 12 shows the percentage of the total loss in grade in rough sugar-pine lumber, No. 2 shop and better, which resulted from blue and brown stain during air seasoning at such a yard.

TABLE 12.—*Percentage of total loss in grade in rough sugar-pine lumber.*

Defect.	Thickness in quarter inches.							Total.
	4/4	5/4	6/4	8/4	10/4	12/4	16/4	
	Percentage of loss.							
Blue stain	19.67	3.94	3.35	3.56	.....	.....	.....	5.09
Brown stain	10.70	4.33	44.29	39.33	2.01	.....	.....	35.87
Blue and brown	4.44	5.46	4.63	6.06	.....	.....	.....	5.38
Total	.....	.....	.....	.....	.....	.....	.....	46.34

In cooler mountain yards the loss from blue stain is much greater than that indicated in this table, and the loss from brown stain much less. Brown stain develops rapidly in kiln drying, and for this reason but comparatively little sugar-pine lumber is artificially

seasoned. Heavy thick boards cut from the sapwood are especially subject to brown stain, while heartwood boards seldom stain except under the "stickers."

Table 13 gives the results secured from piles at a representative mill in the central Sierras, elevation 2,500 feet. These results should be considered simply as illustrations of what has occurred under certain specific conditions. The study has not yet progressed far enough to allow of general conclusions.

At this mill all sugar pine is air seasoned. The No. 3 shop and better is cut principally 6/4 in thickness, although 4/4, 5/4, 8/4, and 10/4 material is manufactured. Depreciation increases with the thickness of the lumber.

The piles of No. 3 shop and better were put up with three 2 by 4 by 16 inch rough-dry white-fir stickers and three 8-inch chimneys. The pile foundations had a slope of 1 inch to the foot. Piles were roofed and sun covers were used on highest grade material.

TABLE 13.—*Depreciation in various grades of sugar-pine lumber during air seasoning at a mill in the central Sierras, California.*

Original grade and thickness.	Length of time in pile.	Total contents pile.	Amount lowered in grade.	Value loss.
		Feet b.m.	*Feet b.m.*	
1, 2, and 3 clear—8/4	Aug. 5, 1914, to Oct. 14, 1914	10,244	2,086	$3.71
1, 2, and 3 clear—6/4	July 14, 1914, to Oct. 14, 1914	4,371	75	.37
No. 1 shop—6/4	May 31, 1914, to Oct. 13, 1914	5,334	51	.10
No. 1 shop—6/4	May 1, 1914, to Oct. 10, 1914	4,582	7	.....
No. 1 shop—8/4	Aug. 20, 1914, to Oct. 10, 1914	27,606	810	.30
No. 2 shop—6/4	July 24, 1913, to June 13, 1914	4,842	260	.42
No. 2 shop—6/4	Oct. 30, 1913, to Oct. 1, 1914	16,585	207	.10
No. 2 shop—6/4	Apr. 28, 1914, to Oct. 1, 1914	6,733	.....	.....

The summer depreciation at this mill in connection with air seasoning of sugar pine appears to be about $1.90 per 1,000 feet for Nos. 1, 2, and 3 clear, 15 cents for No. 1 shop, and 12 cents for No. 2 shop. In addition to this, it is estimated that about 1 per cent of the material depreciates one grade during the winter.

Upon the basis of this study, the following suggestions are offered for decreasing loss through depreciation in grade during air seasoning.

(1) Cut thick stock (8/4 and thicker No. 2 shop and better) early in the season so as to allow time for drying.

(2) Clear away vegetation around piles.

(3) Keep rear pile foundations far enough off ground to allow of good air circulation.

(4) Provide a roof with 4-foot extensions front and rear for piles of high-grade pine left in yard over winter.

(5) Provide sun covers during summer for piles of high-grade material.

(6) Provide shed capacity for as much dry lumber as possible to be held over winter.

(7) Whenever possible, take down lumber as soon as it is dry.

(8) Pile each length of lumber separately.

(9) Surface stickers when blackened by stain.

(10) Whenever possible, saw 8/4 and thicker pine stock either all sap or all heart.

MARKETS.

Sugar pine is being called upon more and more each year to take the place of eastern white pine (*P. strobus*), which for the past two centuries has represented the standard of excellence, not only in America, but in many foreign markets as well. The development of new markets in recent years has made possible the introduction of sugar pine in South America, the islands of the Pacific, and the Orient, and, wherever introduced, it is meeting with the same general success which has characterized its entrance into the markets once wholly supplied by white pine. In large dimensions it has already largely supplanted the latter. Its uniformly high quality is gradually gaining for it well-merited recognition in many specialized industries. The leading manufacturing industries along the Pacific coast, from Seattle to Los Angeles, are dependent largely upon sugar pine for the high-grade products for which white pine has been essential in other parts of the United States. The wood-using industries of the coast consume nearly 60,000,000 feet annually, the manufacturing plants of California alone working up 35,000,000 feet (exclusive of bridge construction, sluicing, dimension stock, and general building material). Fifteen million feet are shipped annually into the territory lying between the Rocky Mountains and the Atlantic seaboard, and 10,000,000 feet go to foreign ports.

USES.

In 1908 the amount of white pine manufactured was 33 times the amount of sugar pine; in 1911 the ratio was reduced to 27 to 1, primarily because of the decrease in the supply of white pine and in a lesser degree because of an increase in the cut of sugar pine. In 1911 sugar pine ranked twenty-fourth in the United States in the amount of sound lumber produced.

TABLE 14.—*Amount of sugar-pine lumber used in various California industries in 1910.*

Industry.	Feet used, b. m.	Per cent of total.	Industry.	Feet used, b. m.	Per cent of total.
Boxes and packing	20,536,000	58.763	Sash, doors, blinds, general millwork	11,930,303	34.140
Brushes	3,440	.010	Ship and boat building	75,000	.220
Elevators	15,000	.043	Tanks	10,750	.031
Fixtures	150,000	.430	Trunks and valises	11,000	.031
Frames and molding	2,730	.008	Vehicle parts	1,000	.003
Furniture	364,410	1.043	Wood carvings	3,000	.008
Musical instruments	4,700	.014	Woodenware and novelties	418,563	1.200
Instruments, professional and scientific	500	.001	Miscellaneous	40,000	.120
Machine parts	4,000	.012			
Patterns	59,350	.113	Total	34,946,956	99.9
Planing-mill products	1,317,060	3.770			

Table 14 shows the amount of sugar-pine lumber used in various California industries during the year 1910. Exact figures for all industries are not available, but those in the table are sufficiently accurate to give a fairly reliable indication of the value of the species for various purposes. It will be noted that a large percentage of the box lumber is used locally.

With the advent of the sawmill in California, the more accessible stands of sugar pine were eagerly sought by the lumbermen because of the superior quality of the lumber. Its durability, lightness, and softness as compared with other available woods led to its use for shakes, flumes, sluice boxes, bridges, houses, barns, fences, and numerous other purposes. Shingle manufacture has to some extent replaced shake making. The early demand created by the fruit industry for trays and boxes was met largely by the sugar-pine mills. With increased use prices were stimulated, good grades increased in value, and the lower grades were utilized in box making. Because of its color, lightness, and freedom from taste and odor, sugar pine has remained a favorite with raisin packers. Some mills work a portion of their output into raisin trays, some specialize in raisin boxes, and nearly all utilize their poorer grades for box shooks or dispose of them to box makers. About 65,000,000 feet are used in California in bridge construction, sluicing, dimension stock, and general building material.

Because of its straightness, softness, freedom from warping and shrinkage, splendid service when exposed to weather, and fine finishing qualities, sugar pine is a very important wood in the manufacture of special-order sash, doors, and blinds, decks of boats, and general millwork. These same qualities make it valuable for frames and stairwork. For pattern and model making, which require woods easily worked, glued, and nailed, it is a close second to white pine. Fixture manufacturers use it for altars, beading, show cases, counters, veneer cores, shelving, and drawers. Freedom from taste and odor make it especially valuable for druggists' drawers, for compartments for spices, coffee, tea, rice, sugar, and other provisions, and for shelving. Furniture manufacturers turn it into backing, built-in dressers, sideboards, carved work, core stock, table frames, and tops. Tanks, hot-grease vats, troughs, and water boxes, requiring freedom from taste and permanence, are frequently of this wood. Its lightness recommends its use for special trunks and sample cases. Its straight grain and permanence give it a place in the manufacture of piano and pipe-organ keys and actions, and player pianos; and the same qualities, together with lightness, place it among the best woods for drawing boards and extension level rods.

Large quantities are used by planing mills in the manufacture of cut siding, interior finish, and moldings. It takes readily the finest enamel finish.

In addition to the above, sugar pine is used for drainboards, elevator floors, brushes (brush blocks), apiary supplies, machine parts, saddles (saddle trees), shade and map rollers, wood carvings of all kinds, oars, slack cooperage, woodenware, bakers' work boards and troughs, dresser brackets, and small turnings and fencing. A large quantity is made into matches.

SHAKE MAKING.

The manufacture of shakes (hand-split shingles) consumes only a small amount of sugar pine, but the industry is unique and is an interesting survival of pioneer methods. In the days of the forty-niners shingles and other modern roof coverings were, of course, not available. The early settlers, however, soon discovered that the straight-grained sugar pine closely resembled the white pine with which many of them had been familiar in the East or Middle West and could readily be split by hand into rough shingles. Piles of refuse made up of the rougher unusable portions of the tree left scattered throughout the forest still testify to their activity, although the industry has diminished with the coming of transportation and the sawed shingle until now it is only practiced by a few old, skilled workmen, or in localities still remote where other roof coverings are prohibitive in price. Tray boards, used in the manufacture of frames or "trays" for fruit drying, were formerly made to a large extent by hand from sugar pine also. Now, however, small shingle and tray mills are finding their way into the mountains and are taking the place of the hand workman.

The shake or tray maker demands the best straight-grained trees. A number are generally tested by chipping before a suitable individual is found. After felling, the tree is sawed into blocks generally 32 inches long for roof shakes and 24 inches long for tray shakes. The blocks are split into bolts, and these are again divided into sections which will allow of splitting out shakes of the width desired. These sections are then placed in a frame, which holds them firmly, while the workman rives the thin shakes with a heavy wide-bladed knife called a "frow," driven by a hand maul. This process requires much skill, and it is fascinating to watch a skilled workman engaged in it. Roof shakes are usually 32 inches long, 5 inches wide, and three-sixteenths of an inch thick on the inner edge; tray shakes are 24 inches long, 6 inches wide, and one-fourth inch thick.

The making of shakes from green timber results in the waste of about 25 per cent of the tree, and is therefore an undesirable practice. The use of dead sugar pines, both standing and down, for shakes is encouraged by foresters, however, since in this way partial utilization of merchantable material that would otherwise be wasted can be secured.

STUMPAGE PRICES.

Theoretically the stumpage value of a given body of timber is that portion of the difference between the cost of operating and the selling value of the manufactured product remaining after a reasonable profit has been deducted for the operator. National Forest stumpage is appraised on this basis. Thus stumpage values increase or decrease directly as the selling value of the product, and inversely as the cost of operation. Stumpage values, however, trend steadily upward with much less fluctuation than there is in lumber prices.

Generally speaking, the value of the stumpage on different tracts in the same general locality varies with the kind and quality of timber, ease of logging, and general accessibility of the tract to the market.

The value of private stumpage is materially affected by carrying and holding charges, which consist of the cost of fire protection, taxes, and interest. With interest at 6 per cent, the total annual carrying cost is probably about 8 per cent of the value. This annual cost must be compounded; therefore, stumpage must double in value about every decade in order to make the holding of it profitable.

It is only in comparatively recent years that separate stumpage values have been placed on sugar pine as distinguished from yellow pine. The bulk of the pine timberlands in California in private ownership were acquired from the Government under the timber and stone act at $2.50 per acre. These claims were ultimately disposed of to speculators upon an acreage basis which meant anywhere from 10 cents to 20 cents per 1,000 feet board measure. Especially accessible or well-located tracts brought from 30 cents to 50 cents per 1,000 feet. This condition existed until the latter part of the nineties, when more extensive operations brought about a rise in stumpage values. Accessible sugar-pine stumpage in 1900 and 1901 was worth about $1. By 1904 and 1905 private sugar pine stumpage was sold at from 75 cents and $1 in Siskiyou County and the northern Sierras to $1.50 and $1.75 in the southern Sierras. During 1905 considerable sugar pine was sold from the National Forests in the southern Sierras at $2 per 1,000 feet. These same sales included yellow pine at $1.50, white fir at 75 cents, and incense cedar at 50 cents.

The value of privately owned stumpage has increased still further. Sales are now made on the basis of board-measure estimates or actual scale. However, in most transactions sugar pine and yellow pine are included at the same rate, and in many cases a flat rate is still made covering all species. For well-located timber this flat rate is in the neighborhood of $1.75 to $2.25 per 1,000 feet; or sometimes $2.50 per 1,000 feet if the proportion of inferior species is light. Assigning to sugar pine its proper share of this average price would make it worth from $3 to $4 per 1,000 feet. Timber less advantageously located is sold at an average rate of $1.25 to $1.50 per 1,000 feet.

The range of stumpage rates secured for sugar pine in sales of National Forest timber in California made during recent years is as follows:

	Maximum.	Average.	Minimum.
North Coast Range and Sierras	$3.50	$3.40	$2.75
Central Sierras	3.50	2.75	2.50
Southern Sierras	3.50	3.00	2.75

Within the California National Forests extensive bodies of timber containing sugar pine are now being offered for sale, and complete information regarding these tracts can be secured from the district forester at San Francisco, Cal. Operators in National Forest timber are not required to make large advance payments; and the stumpage is not taxed, although the State derives a direct compensating revenue from all sales, through the United States Treasury. Operations in this class of stumpage are somewhat more expensive than on private lands because from 10 to 35 per cent of the younger timber is left on the area, and the piling and burning of refuse is required as well as the cutting of unmerchantable trees which are a fire or disease menace. These costs are taken into account in the appraisal, however, and are borne by the stumpage and not by the operator.

GROWTH AND YIELD.

HEIGHT GROWTH.

One of the most remarkable characteristics of sugar pine is its ability to sustain a rapid rate of growth up to a very advanced age. Its rate of growth in height is comparatively slow; up to about 100 years of age it is less than that of yellow pine. At this point it forges ahead and maintains its lead. In the most favorable situations, during its first century of life, sugar pine makes an average annual height growth of about 1 foot; during its second century, about 0.6 foot; and during its third century, about 0.4 foot.

Foresters are interested principally in the rate of growth in the second-growth stands rather than in virgin stands, since this indicates the possibilities of the species under management. In the case of sugar pine it is very difficult to find representative second-growth stands, because there are but few sufficiently old cuttings and because sugar pine second-growth never occurs in dense young stands as yellow pine does, but always in open, mixed stands where growth is not forced so strongly by competition for light. Table 15 was prepared from analyses of 29 rapid growing, young, second-growth sugar pines. The contrasting yellow pine measurements were taken in thrifty, dense, second-growth stands in Nevada County, Cal.

F—98911

FIG. 1.—LIVING PINE DAMAGED BY RECURRING FIRES, LASSEN COUNTY, CAL.

F—6—D5

FIG. 2.—NATIONAL FOREST TIMBER SALE.

Area after cutting, showing refuse piled for burning and thrifty groups of yellow and sugar pines left, Tulare County, Cal.

TABLE 15.—*Height growth of saplings and poles in the Sierra Nevada Mountains.*

Age.	Sugar pine total height.	Yellow pine total height.	Age.	Sugar pine total height.	Yellow pine total height.
Years.	*Feet.*	*Feet.*	*Years.*	*Feet.*	*Feet.*
10	4	12	40	62	69
20	19	34	40	73	82
30	45	52	60	82	91

Height measurements of over 700 seedlings and saplings taken on virgin forest areas show the average height of young sugar pines grown under such conditions to be only about 5 feet at the end of 40 years. The above table indicates a height of 62 feet at this age. This startling difference shows that the tree responds quickly to proper conditions of light, soil, and moisture, and is an encouraging indication of what may be accomplished by proper management.

In order to show the height growth of trees over 60 years of age, 287 trees were measured in four representative localities in the virgin forests of the Sierra Nevada Mountains. Table 16 shows the rates of height growth in the best and poorest situations and also the average growth on all plots.

TABLE 16.—*Maximum, minimum, and average heights based on age in virgin California forests (Sierra Nevada Mountains).*

Age.	Total height.			Maximum current annual growth.	Age.	Total height.			Maximum current annual growth.
	Maximum.	Average.	Minimum.			Maximum.	Average.	Minimum.	
Years.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Years.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
20	8	.....	.....	0.40	220	173	148	127	0.40
40	24	23	.....	.80	240	180	153	129	.35
60	49	45	.....	1.25	260	187	158	131	.35
80	84	72	61	1.75	280	194	162	132	.35
100	111	92	77	1.35	300	200	167	134	.30
120	127	106	91	.80	320	206	171	135	.30
140	139	118	103	.60	340	212	174	136	.30
160	148	127	112	.45	360	218	177	137	.30
180	157	135	119	.45	380	.....	180	.....	.....
200	165	142	124	.40	400	.....	183	.....	.....

It is evident that the period of most rapid growth is from the eightieth to the hundredth year of life in the best localities, at which time the annual increase in height amounts to 1.75 feet. At the age of about 110 years the rate of height growth has fallen off to such an extent that current annual growth is less than the mean annual growth or average annual growth for the entire growing life of the tree.

MERCHANTABLE AND CLEAR LENGTHS.

From a commercial standpoint the merchantable length of a species (the length of that section of the tree which can be utilized and the clear length free from limbs and yielding high-grade lumber) is more

important than the total height. Because of its straightness, a very large proportion of the bole of a sugar pile can be utilized. Furthermore, the lower branches of the crown fall off at a comparatively early age, leaving an unusual clear length averaging 50 feet in nature stands and not infrequently reaching 80 feet. A table, based on a large number of actual measurements, showing the merchantable length of trees of various diameters and heights will be found in the Appendix.

DIAMETER GROWTH.

Sugar pines of the largest diameters are found on the best sandy loam soils in fairly open situations. Trees in dense forest, in competition with others for light, are obliged to devote their energy to height growth largely. Table 17 shows maximum, average, and minimum diameters based on age in virgin stands.

TABLE 17.—*Minimum, average, and maximum growth in diameter, on basis of age, California.*

Age.	Diameter breast-high outside bark, in inches.			Age.	Diameter breast-high outside bark, in inches.		
	Maximum.	Average.	Minimum.		Maximum.	Average.	Minimum.
Years.				*Years.*			
20	0.4	0.2	.....	260	60.1	44.9	32.4
40	4	2.5	.....	280	63.5	47.2	34.3
60	9.7	7.5	5.8	300	66.9	49.3	36.1
80	16.7	13.0	9.2	320	70	51.4	37.9
100	24.1	18.1	12.6	340	73.3	53.5	39.5
120	30.4	22.7	16.2	360	76.1	55.5	.....
140	35.6	26.8	19.2	380	.....	57.3	.....
160	40.3	30.5	21.8	400	.....	59.1	.....
180	44.9	33.9	24.2				
200	49.1	37.0	26.4	Number of stump analyses	20	474	22
220	52.8	40.0	28.6				
240	56.5	42.5	30.5				

The measurements upon which Table 17 is based were taken for the purpose of showing the effect of locality upon diameter growth rather than the effect of various factors, such as soil, light, and moisture, within a given locality. The maximum measurements were secured among dominant trees within the western central Sierras, the best range of the species. The minimum measurements were taken among the same class of trees in Siskiyou County, northern California, toward the limit of the range. The average was obtained by averaging the measurements taken in eight localities throughout the State. The effect on the growth of unfavorable factors within a given locality approximates the effect of an unfavorable change in latitude or altitude, however; therefore, the average growth shown in the tables is indicative of the growth that trees somewhat crowded for light, or growing on poorer soils, might make in a more central portion of the range of the species. In the same way, the minimum

figures represent roughly the results under a still greater degree of light or soil suppression.

It appears from the diameter-growth table that the maximum current diameter growth occurs between 80 and 100 years, which is also the period of maximum height growth. The maximum average annual growth for this 20-year period is 0.37 inch. The rate of growth in diameter decreases less rapidly, however, than the rate of height growth, the current annual exceeding the mean annual growth up to about the hundred and forty-fifth year. Usually the height growth of a tree species culminates before the diameter growth. Whether the sustained rate of height growth apparent in this species is attributable to the fact that the trees measured grew in virgin forest, where their light requirements were not satisfied during youth, or whether this is an inherent peculiarity, has not yet been fully determined, and can not be until older, more normal second-growth stands are available for study.

VOLUME GROWTH.

Table 18, showing the growth in volume of sugar pine, is derived from tables of average growth in diameter and height at various ages and a volume table for trees of various diameters and heights (see p. 37–38, Appendix). The striking feature shown by this table is the great age to which the tree sustains volume production. The current annual volume growth remains above the mean annual growth for over 400 years, over 300 years after height and diameter growth have culminated. At 100 years of age the annual rate of volume growth is 2 cubic feet. It then increases steadily up to an annual rate of 5½ cubic feet at 350 years. The rate of volume growth remains practically constant from that age up to 460 years. No information to indicate its behavior at a greater age has been collected.

TABLE 18.—*Growth in volume, on the basis of age, diameter, and height of average dominant trees, California Sierras.*

Age.	Average.		Volume.		Age.	Average.		Volume.	
	Diameter outside bark at breast height.	Total height.	Cubic feet outside bark.	Board feet (Scribner Decimal C rule).		Diameter outside bark at breast height.	Total height.	Cubic feet outside bark.	Board feet (Scribner Decimal C rule).
Years.	*Inches.*	*Feet.*			*Years.*	*Inches.*	*Feet.*		
20	0.2	8	.....	.....	220	40.0	148	530	2,830
40	2.5	23	.....	.....	240	42.5	153	630	3,460
60	7.5	45	.....	.....	260	44.9	158	733	4,120
80	13.0	72	31	110	280	47.2	162	838	4,840
100	18.1	92	71	240	300	49.3	167	944	5,570
120	22.7	106	126	490	320	51.4	171	1,050	6,020
140	26.8	118	192	850	340	53.5	174	1,158	7,750
160	30.5	127	268	1,290	360	55.5	177	1,270	7,740
180	33.9	135	348	1,760	380	57.3	180	1,380	8,380
200	37.0	142	435	2,250	400	59.1	183	1,488	9,010

Table 19 indicates the comparative rate of volume, diameter, and height growth of sugar pine and two of its common associates, yellow pine and incense cedar. Sugar pine evidently outgrows cedar in all three respects from its fiftieth year. It passes yellow pine in height about the one hundred and tenth year, in diameter about the one hundred and thirtieth year, and in volume about the one hundred and fiftieth year.

TABLE 19.—*Comparative rate of volume, diameter, and height growth of sugar pine and two of its common associates.*

Age.	Species.								
	Sugar pine.			Yellow pine.[1]			Incense cedar.		
	Diameter breast high.	Height.	Volume.	Diameter breast high.	Height.	Volume.	Diameter breast high.	Height.	Volume.
Years.	*Inches.*	*Feet.*	*Board feet.*	*Inches.*	*Feet.*	*Board feet.*	*Inches.*	*Feet.*	*Board feet.*
20	0.2	8	.....	2.3	12	.....	.....	.....	.....
40	2.5	23	.....	6.5	29	.....	3.2	.....	.....
60	7.5	45	.....	11.4	57	.....	6.4	23	.....
80	13.0	72	110	16.1	79	210	9.8	49	.....
100	18.1	92	240	20.0	94	360	13.6	65	70
120	22.7	106	490	23.3	104	610	17.8	75	140
140	26.8	118	850	25.8	112	890	21.3	82	230
160	30.5	127	1,290	28.0	118	1,170	23.6	86	310
180	33.9	135	1,760	29.8	123	1,430	25.8	90	390
200	37.0	142	2,250	31.3	127	1,640	27.8	93	490
220	40.0	148	2,830	.....	.....	.....	29.8	96	600
240	42.5	153	3,460	.....	.....	.....	31.7	98	720
260	44.9	158	4,120	.....	.....	.....	33.6	101	850
280	47.2	162	4,840	.....	.....	.....	35.4	103	970
300	49.3	167	5,570	.....	.....	.....	36.9	105	1,090
320	51.4	171	6,020	.....	.....	.....	38.2	115	1,200
340	53.5	174	7,050	.....	.....	.....	39.2	118	1,290
360	55.5	177	7,740	.....	.....	.....	40.1	119	1,380
380	57.3	180	8,380	.....	.....	.....	40.9	120	1,440
400	59.1	183	9,010	.....	.....	.....	41.6	121	1,510

[1] From Forest Service Bul. No. 69, "Sugar Pine and Western Yellow Pine in California," by Albert W. Cooper.

YIELD.

The average merchantable stand per acre of sugar pine varies widely throughout its range. In general it ranges from 2,000 to 16,000 board feet, which represents from 12 to 60 per cent of the total stand. However, within the sugar pine-yellow pine type considerable areas show an average of 20,000 feet per acre, representing 40 per cent of the whole

TABLE 20.—*Maximum stands of sugar pine within the sugar pine-yellow pine type in three localities.*

Locality.	Western yellow pine.		Sugar pine.		White fir.		Incense cedar.		Douglas fir.		Total.	
	Bd. ft.	*P. ct.*	*Bd. ft.*	*P. ct.*	*Bd. ft.*	*P. ct.*	*Bd. ft.*	*P. ct.*	*Bd. ft.*	*P. ct.*	*Bd. ft.*	*P. ct.*
Tahoe National Forest.....	11,030	22.7	18,440	37.9	7,174	14.8	1,880	3.9	10,050	20.7	48,574	100
Stanislaus National Forest.	13,750	27.4	20,700	41.2	11,370	22.6	4,430	8.8	.....	.....	50,250	100
Yosemite National Park..	14,688	23.9	20,538	33.4	19,269	31.4	6,904	11.3	.....	.....	61,399	100

Table 20 shows maximum stands of sugar pine within the sugar pine-yellow pine type in three representative Sierra Nevada range localities, as well as the proportion of other species in mixture.

The heaviest single acre estimate of which the Forest Service has a record is 192,000 feet b. m., which amounted to 75 per cent of the total estimate for the acre plot. Acres containing 75,000 to 150,000 feet b. m. are frequently found within the maximum range of the species. The largest single tree measured by the Forest Service scaled 40,710 feet b. m.

TABLE 21.—*Yellow pine type (quality II). Yield per acre and increment per acre per annum of all species.*

Age.	Yield per acre.	Increment per acre per annum.	Age.	Yield per acre.	Increment per acre per annum.	Age.	Yield per acre.	Increment per acre per annum.
Years.	*Bd. ft.*	*Bd. ft.*	*Years.*	*Bd. ft.*	*Bd. ft.*	*Years.*	*Bd. ft.*	*Bd. ft.*
10	55	5.5	150	15,900	106	290	33,200	114.5
20	220	11	160	17,900	112	300	33,300	111
30	550	18	170	19,900	117	310	33,200	107
40	1,000	25	180	21,900	122	320	33,000	103
50	1,600	32	190	23,800	125	330	32,600	99
60	2,600	43	200	25,600	128	340	32,200	94.5
70	3,500	50	210	27,200	129.5	350	31,700	90.5
80	4,600	57	220	28,700	130.5	360	31,100	86.5
90	5,900	66	230	29,800	130	370	30,500	82.5
100	7,300	73	240	30,900	129	380	29,900	78.5
110	8,800	80	250	31,700	127	390	29,200	75
120	10,400	87	260	32,300	124	400	28,500	71.2
130	12,100	93	270	32,800	121			
140	14,000	100	280	33,100	118			

TABLE 22.—*Fir-sugar pine type (quality II). Yield per acre and increment per acre per annum of all species.*

Age.	Yield per acre.	Increment per acre per annum.	Age.	Yield per acre.	Increment per acre per annum.	Age.	Yield per acre.	Increment per acre per annum.
Years.	*Bd. ft.*	*Bd. ft.*	*Years.*	*Bd. ft.*	*Bd. ft.*	*Years.*	*Bd. ft.*	*Bd. ft.*
10	80	8	230	40,500	176	450	88,400	196.5
20	300	15	240	43,700	182	460	88,700	193
30	700	23	250	47,000	188	470	88,700	189
40	1,300	32	260	50,300	193.5	480	88,500	184
50	2,000	40	270	53,600	198.5	490	88,200	180
60	2,900	48	280	57,000	203.5	500	87,700	175.5
70	3,900	56	290	60,200	207.5	510	87,000	170.5
80	5,100	64	300	63,500	211.5	520	86,200	165.5
90	6,500	72	310	66,500	214.5	530	85,200	161
100	8,000	80	320	69,200	216	540	84,100	155.5
110	9,600	87.5	330	71,800	217.5	550	82,800	150.5
120	11,400	95	340	74,200	218	560	81,500	145.5
130	13,400	103	350	76,300	218	570	80,100	140.5
140	15,500	111	360	78,300	217.5	580	78,700	135.5
150	17,800	118.5	370	80,100	216.5	590	77,300	131
160	20,200	126	380	81,700	215	600	75,900	126.5
170	22,600	133	390	83,200	213.5	610	74,500	122
180	25,200	140	400	84,500	211.5	620	73,100	118
190	28,000	147.5	410	85,700	209	630	71,600	113
200	31,000	155	420	86,600	206	640	70,000	109.5
210	34,000	162	430	87,400	203			
220	37,200	169	440	88,000	200			

Since sugar pine never occurs in pure or even-aged stands, the problem of predicting the acreage yield at various ages is a complex one which has not as yet been satisfactorily solved. Tables 21 and 22 indicate the probable yield of all species in the yellow pine and

fir-sugar pine types of which this species forms a part. They were prepared from data collected on the Plumas Forest (Plumas County, Cal.) during 1912 and represent results on areas of average productiveness.[1]

These tables indicate that the maximum volume is produced at 300 years in the yellow-pine type and at 460 years in the fir-sugar pine type. The highest rate of volume production, however, occurs at 180 years in the former type and at 280 years in the latter.

MANAGEMENT.

The manner in which any tract of forest land is handled depends, of course, entirely upon the wishes or necessities of its owner. If present financial considerations demand it, clear cutting of all merchantable trees must be practiced. Some lumbermen, by following this policy, jeopardize the future of the forest, encourage species of low value, and postpone a second cut for at least a century. If esthetic considerations govern, then expenditures may be made which will never yield a direct monetary return. If, however, the owner desires to make his manufacturing business permanent and is willing partially to subordinate present to future returns, he must determine what classes of trees can be most profitably left to furnish seed, shade, and a second cut; what protective measures are necessary and practicable to prevent the destruction of the trees left, both during logging and later; and what amount he can spend annually or periodically in artificial reforestation or thinnings if necessary. There is a marked tendency now toward close utilization of all pines cut, toward leaving trees that are evidently immature, and toward protecting the remaining stand from fire and insects.

High taxes tend to prevent the practice of management on private lands. Naturally lumbermen can not afford to hold land for a second cut when taxes and other carrying charges will in the meantime amount to more than the possible prospective profit. With low taxes and carrying charges operators can afford to leave and to protect young trees and trees of inferior species until they become more valuable. Since lands in Federal ownership are not burdened with as heavy carrying charges as private holdings, and since it is the evident duty of the Government to experiment and lead in the field of forestry, the cuttings on the National Forests are naturally the best examples of present-day forest-management methods.

NATIONAL FOREST METHODS.

The following principles govern cutting in the sugar-pine type on National Forests:

It is the general aim to improve the forest by cutting so as to put it in condition to produce a sustained yield in future years when that becomes necessary.

[1] See Appendix to Plumas Working Plan, by Barrington Moore, forest assistant, February, 1913.

The exact age at which sugar pine and the various species which enter into combination with it should be cut to yield the highest return is dependent upon so many variable factors that it is impossible to determine it with accuracy at present. Even if this were determinable, however, such a cutting age (rotation) could not be strictly adhered to, because, under present economic conditions, demand and accessibility must largely determine the time and place of cutting. We know, however, that stands of yellow pine and sugar pine reach their highest rate of volume production at about 180 years. On average sites the diameter of sugar pine is approximately 33 inches, and of yellow pine 30 inches at this age. White fir and cedar, the two other principal species in mixture, while not so large at this age, are of merchantable size and usually in need of cutting on account of their susceptibility to disease. Therefore, without danger of serious error, stands in which sugar pine is an important tree may be cut down to a diameter of about 30 inches.

This principle is used as a guide in the cutting done in such stands within the National Forests, although the removal of smaller trees and the leaving of larger is practiced whenever necessary for a weighty special reason, such as the elimination of disease or the creation of conditions favorable to reproduction. Diseased trees are always cut and the merchantable portions utilized, since sanitation is as essential to health in a forest as in a human community. Dead trees are a source of danger in time of fire and are felled. The cost of this work to operators—generally from 3 to 7 cents per 1,000 feet—is taken into account in fixing the stumpage rate.

Timber apparently ripe is always harvested, except when it is clear that reproduction can not be secured on the area unless a few trees of this class are left for seed or shade. The condition of the crown of the tree determines which individuals are to be cut. Trees whose crowns are flattened are mature, or are not making profitable growth, and should be removed. It is recognized that sufficient timber must be secured from each tract to make the operation profitable. While this amount varies with the investment and with logging conditions, from 12,000 to 18,000 feet per acre is usually a profitable cut. The removal of this amount should leave a sufficient basis of younger trees for a second cut in from 50 to 60 years. It is expected that lumber prices will have increased by that time to a point which will allow of operating at a profit for a smaller per acre yield.

Practical considerations demand that trees so situated as to be a hindrance to carrying out the most feasible and economical logging plan be cut whether mature or not. This practice is followed in preference to leaving such trees to inevitable injury, which will lessen their growth and perhaps cause disease.

Studies of the grades cut from pine logs of various dimensions indicate that knotty trees under 32 inches in diameter produce largely common and box lumber, which can be marketed at present only at a loss or at a very slight profit. Such trees may profitably be left for seed or protection and to form a part of the next cut, for which they will be more valuable because of increased growth, higher selling prices, and a greater percentage of high-grade product as the result of natural pruning.

The white fir and cedar in sugar-pine stands are now difficult to market at a profit above the bare cost of production. Both of these species have greater prospective than present values—the former for pulp as well as lumber, the latter for pencil stock and other refined uses. It appears to be wise management, therefore, to remove only the dead, diseased, and mature trees which will not remain merchantable until the next cut. Young sugar pine reproduction requires shade in youth, and these species are left to furnish it in preference to others of more value. Their reproduction will endure shade, and is therefore a valuable agent in preventing brush from securing control of cut-over areas.

In applying the above principles on National Forests the cutting is so regulated as to create conditions favorable to the securing of a stand of young trees through natural regeneration, because the perpetuation of the forest depends upon this. Sugar-pine seed is eaten in large quantities by rodents and birds, and since young trees require protection from too severe light for the first 10 years of their life the securing of young growth is rather a difficult problem. Eventually, when transportation and market conditions allow of cutting over areas frequently for a small volume of timber, the shelterwood system of cutting will probably be applied where sugar pine makes up 20 per cent or more of the stand. This system provides for several successive operations separated by short intervals; the first opens up the stand slightly to afford just sufficient light to stimulate the seed-producing capacity of the remaining trees and to secure young growth; the second follows after reproduction has been secured and partially frees it from shade; the third removes the remaining mature trees. At present, however, this system would not pay.

In the sugar-pine type the forest is made up of groups of mature sugar pine and its common associates, interspersed with openings and approximately even-aged groups of younger trees of the same composition, as well as of trees of various ages and species occurring singly. On areas where the occurrence is in groups the clumps of mature trees are cut clean and the immature are left. Sometimes it is necessary to leave a mature tree which may occur in an immature group from which it could not be removed, or to remove a few immature trees from mature groups because of the likelihood of wind damage or to free reproduction from shade. In cuttings of this

nature the reproduction of the more light enduring species, such as yellow pine, white fir, and Douglas fir, take possession of the openings first, and young sugar pines are confined to the zone of partial shade around the groups left. Later, after partial shade has been established in the openings, some sugar pine enters the mixture and tends eventually to outdistance the other trees because of a more rapid and sustained rate of growth. This method of cutting is known as the group-selection system. Generally from 65 to 75 per cent of the board-measure content of the stand is removed.

On areas covered with trees of various ages mingled together the so-called selection system of cutting must be applied. Each tree is subjected to the test of maturity, health, and value of contents. Mature and unhealthy trees are removed. Immature trees, or trees of the less valuable species, such as fir and cedar, are left to furnish shade and protection. Whenever it is necessary to remove a few pines not fully mature in order to make the operation profitable, those that will yield the highest grade product are selected.

Such a cutting results in maximum openings of an acre in the forest cover and in the removal of from 75 to 85 per cent of the mature stand. These openings will, it is believed, on fairly favorable situations restock with yellow pine, fir, and cedar, followed by sugar pine when proper shade conditions have been established, as in the group-selection system.

UTILIZATION.

While logging on private lands is still wasteful, utilization is far more complete than it was 10 or 15 years ago. At that time only the larger pine trees were cut. Stumps were sometimes cut as high as 4 feet and only the clear length of the trees removed. Wasteful lumbering in the past has been due primarily to low stumpage values and poor market conditions. The cost of transportation has been another important factor, since only the better class of material could be hauled to market at a profit.

With the rapid growth of the lumber industry in California more modern methods of logging have been adopted. Some concerns cut only the best fir and cedar, but pines are frequently utilized to a diameter of 10 inches in the tops. Stumps are usually cut from 18 to 24 inches high. Even tops and limbs are, in favorable localities, utilized for firewood.

In sales of National Forest stumpage the closest utilization consistent with modern logging methods and market conditions is practiced. Stumps are cut 18 inches or less in height; trees are utilized to a top diameter of at least 10 inches in the case of pines and 12 inches for other species, and all species are logged. Pine logs which contain 33 per cent, and logs of other less valuable species which contain 50 per cent sound lumber, are considered merchantable.

PROTECTION.

No scheme of management should be undertaken or can be successfully carried out unless the area involved is adequately protected from destructive influences. Fire, insects, and disease are the most active agents of tree destruction. Of these, fire is the most important, because it not only kills all young growth and injures or kills mature trees, but also depletes the soil by consuming the humus, and destroys other forms of property as well as life. Within the National Forests of California during 1914, 1,304 fires occurred, causing an estimated loss of about $77,000.

Virgin stands in which no cutting is being done should be protected by eliminating the causes of fire as much as possible by the use of suitable warning signs and other regulation and by a systematic patrol for the detection of fires. The efficiency of any patrol is considerably increased by installing telephone lines and by a good system of roads and trails constructed, wherever possible, so as to act as firebreaks. Under such conditions one patrolman, at a salary of $300 for himself and horse for the danger season of four months, should take care of from 25,000 to 30,000 acres. An adequate patrol system should not cost over 2 cents per acre per annum.

Fire risk naturally increases when lumbering operations start, because of the presence of engines and men as well as slash. Precautions are therefore particularly necessary. The most effective precaution is the disposal of slash by burning. On National Forest sale areas in California all slash is piled at once in tepee-shaped piles and burned at a favorable season. This operation costs from 20 to 30 cents per 1,000 feet board measure.

All engines used in connection with logging should, when possible, burn oil. If this is not feasible, they should be equipped with adequate spark arresters and with hose and water under pressure for putting out fires which start in their vicinity. Supplies of shovels and axes should be readily available at convenient points about the operation.

The importance of the control of insects and tree diseases is only secondary to the control of fire in managed forests.

PLANTING.

On treeless areas, or where natural reproduction can not be secured by leaving seed trees, planting must be undertaken. Thus far, in California, National Forest tree planting has been confined principally to treeless areas which once undoubtedly bore forests. The brush fields common in northern California are representative of this type of land. On pine lands where practically all of the trees are mature it may be found after planting methods have been perfected and cheapened that it is more profitable to cut all of the timber and plant, but at the present time this is not considered feasible.

In a year when sugar-pine seed is plentiful it can be collected in large quantities from felled trees or from standing trees by climbing and cutting off the cones with an improvised cutting knife on a pole for from 50 to 60 cents per pound. Collecting small quantities is more expensive.

Attempts have been made to restock denuded areas with sugar pine by sowing the seed directly in the field either broadcast or in prepared seed spots. Both of these methods have failed absolutely. The seed has either been devoured by rodents before germination or the young trees have succumbed to the effect of drought during the first season.

A small supply of sugar-pine stock for field planting is now being produced annually at the Pilgrim Creek Nursery, near McCloud, Cal., on the Shasta Forest, and experiments in planting have been conducted near there and also in Plumas County. So far it has been very difficult to produce satisfactory trees, both because the seed germinates very slowly and incompletely and on account of the unsatisfactory development of the seedlings and transplants. Results indicate that 3-year-old trees are the best adapted to field conditions. Plantations of 3-year-old trees have cost, on an average, about $22 per acre, including all items. This cost is excessive and is only justified by the value of the experiments. If this preliminary work is fairly successful, costs can be decreased as the scale of work is increased.

MANAGEMENT OF PRIVATE TIMBERLANDS.

Private timber holdings may be divided into two principal groups—individual holdings and corporate holdings. The individual holdings are generally smaller than the corporats ones, and it is usually the natural desire of individual holders to secure all possible profit from their lands during a lifetime. It is undoubtedly just as good business for such owners to protect their capital (standing merchantable timber) against loss as it is for the proprietor of any other business to carry insurance. Protection of cut-over areas, except in so far as is necessary to prevent the loss of merchantable timber adjoining or equipment, however, is not at present profitable to this class of owners.

Corporations may look further into the future, since their life is indefinite. Thus far they have found it more profitable to extend their operating life by adding to their holdings rather than to attempt to maintain their cut-over lands in such a condition of productiveness that a profitable second crop can be derived from them by the time the entire area has been cut over. It is self-evident, however, that as the supply of stumpage decreases its value will increase until it equals the cost of producing timber. It is fair to assume, therefore,

that a reasonable present outlay in immature timber left on cut-over areas and in the protection of these areas will show a return at that time, or at least that the stumpage thus produced will be as cheap as that obtainable by purchase.

In order to secure a second crop within a reasonable time in the sugar pine-yellow pine type, owners should follow the Forest Service methods of cutting as closely as the necessities of their business will allow, particularly as regards close utilization, leaving immature timber and timber of species which have a greater prospective than present value, such as white fir and cedar.

On areas cut over conservatively protection from fire must be provided. Promiscuous burning of the slash has been frequently advocated. This method involves the destruction of a large amount of young growth and serious injury to trees left standing, and therefore can not be indorsed. Careful piling and burning of brush, the method practiced by the Forest Service, at a cost of 25 cents per 1,000 feet, is probably too expensive for private owners. A compromise between these two methods should prove fairly effective. The brush on portions of cut-over areas located where there is unusual fire risk should be roughly piled away from living trees and clumps of young growth and carefully burned after the fall rains, when fires can be controlled. Piling and burning of this character can be accomplished for from $1 to $1.50 per acre. On all other portions of the cut-over area the slash should be distributed over the ground as evenly as possible when the trees are trimmed and measures adopted to prevent fires or to put out quickly those that are started.

The Forest Service offers to protect, under cooperative agreement, the lumber holdings of owners of areas within California National Forests at a cost of from 1½ to 4 cents per acre, and will also gladly give advice to those who wish to install an independent scheme of protection.

APPENDIX.

VOLUME TABLE.

Table 23 is based upon actual measurements of 910 felled sugar-pine trees, taken by the Forest Service in California. No allowance was made for defect. In field estimating trees are tallied by two inch, breast-high (4.5 feet), diameter classes, and by the number of logs they contain. Their contents in feet board measure may then be obtained from this table.

TABLE 23.—*Sugar pine (Pinus lambertiana), Lassen, Plumas, Sierra, Stanislaus, and Tahoe National Forests, Cal. Curved, Scribner Decimal C.*

Diameter breast high.	Number of 16-foot logs.												Diameter inside bark of top.	Basis.
	1	2	3	4	5	6	7	8	9	10	11	12		
	Volume—Board feet in tens.													
Inches.													*Inches.*	*Trees.*
10	4	8												
12	4	9	15	22									8	
14	5	10	17	24									8	1
16	6	10	19	27	39								8	2
18	7	13	20	30	43								9	7
20	8	17	25	37	50	65	79						9	28
22	10	22	31	43	57	74	89						9	23
24	13	28	40	53	67	83	100	122					9	35
26		35	50	64	78	96	113	136					9	35
28		45	63	78	92	110	128	152					10	44
30		55	80	94	108	125	144	170	189				10	53
32			95	113	127	145	163	192	218				10	50
34			115	135	149	166	187	217	247				10	38
36			140	160	173	191	213	246	279	310			11	36
38			168	183	200	220	245	278	313	346			11	40
40			195	210	229	253	280	313	349	386			11	41
42				240	261	288	319	354	390	427	463		11	43
44				271	295	325	359	398	435	473	515		12	39
46				303	330	365	401	445	482	523	567		12	31
48				337	366	405	446	493	532	576	623		12	43
50				368	401	446	493	544	586	630	681	749	12	41
52				400	438	489	544	598	642	686	740	818	12	56
54				432	472	532	597	653	698	742	801	885	13	36
56				465	510	575	652	711	756	800	862	953	13	25
58					550	619	709	769	814	860	923	1,022	13	25
60					590	660	764	829	872	921	987	1,090	14	28
62					630	704	820	886	930	983	1,051	1,159	14	25
64					670	760	876	943	990	1,046	1,116	1,227	14	27
66						820	933	1,000	1,053	1,109	1,181	1,297	14	11
68						890	989	1,058	1,115	1,173	1,250	1,366	15	9
70						960	1,048	1,117	1,177	1,239	1,319	1,434	15	17
72						1,030	1,110	1,176	1,240	1,305	1,388	1,502	15	6
74							1,175	1,235	1,303	1,370	1,456	1,570	16	2
76							1,235	1,296	1,368	1,435	1,523	1,639	16	6
78							1,290	1,358	1,431	1,500	1,590	1,707	16	4
80							1,348	1,420	1,497	1,565	1,659	1,778	16	3
														910

Average stump height 1.3 to 3.1 feet.
Logs scaled in commercial lengths as cut.
Figures outside heavy lines are from extension of original table.

TABLE 23.—*Sugar pine (Pinus lambertiana), Lassen, Plumas, Sierra, Stanislaus, and Tahoe National Forests, Cal. Curved, Scribner Decimal C*—Continued.

Diameter breast high.	Total height of tree—Feet.															Diameter inside bark of top.	Basis, trees.
	40	50	60	70	80	90	100	110	120	130	140	160	180	200	220		
	Volume—Board feet in tens.																
Ins.																*Inches.*	
12	6	7	8	10	13	15	18									8	
14	7	8	9	10	14	16	20									8	1
16	8	9	10	12	17	20	24	28	33							8	1
18		10	12	16	20	23	29	33	39							9	7
20		12	15	20	25	30	35	40	47	60	71					9	28
22		17	21	27	33	37	42	48	57	68	80					9	22
24			31	36	41	46	50	59	69	79	90					9	35
26			42	46	52	57	63	72	82	93	103	126				9	35
28				58	65	70	78	87	97	109	120	143				10	44
30				72	80	86	96	103	115	128	140	163				10	52
32				86	95	105	115	125	136	149	160	187	230			10	50
34				100	114	127	138	148	160	172	183	213	260			10	37
36				120	136	150	162	174	185	198	209	241	293			11	36
38				144	160	173	189	202	214	225	237	273	328	366		11	40
40					182	195	214	233	247	257	270	310	363	408		11	40
42					205	217	240	264	280	293	308	350	402	452		11	42
44						240	268	294	317	333	350	395	449	501	554	12	38
46						263	298	323	352	377	399	444	500	553	613	12	32
48						286	325	351	389	422	449	500	557	609	670	12	43
50						310	355	380	427	470	501	559	615	667	728	12	41
52								407	463	521	555	618	676	726	786	12	56
54								435	500	576	612	679	736	785	846	13	34
56								463	537	633	671	738	797	847	908	13	25
58								491	574	693	730	797	859	910	973	13	25
60										751	788	857	920	976	1,040	14	27
62										811	845	917	983	1,040	1,106	14	25
64										873	904	977	1,044	1,104	1,173	14	27
66										937	965	1,034	1,105	1,168	1,240	14	11
68										1,003	1,027	1,091	1,165	1,229	1,305	15	9
70										1,070	1,090	1,150	1,224	1,290	1,370	15	16
72										1,140	1,154	1,212	1,284	1,352	1,434	15	6
74										1,210	1,220	1,273	1,345	1,414	1,497	16	2
76												1,336	1,408	1,479	1,560	16	5
78												1,398	1,471	1,543	1,624	16	4
80												1,460	1,533	1,607	1,689	16	3
																	899

The following table is inserted to show the relation between diameter, total height, and merchantable length of sugar-pine trees:

TABLE 24.—*Merchantable length and diameter of top logs inside bark, sugar pine.*

Diameter breast high.	Total height.[1]	Merchantable length.	Average top diameter inside bark.	Basis number of trees.	Diameter breast high.	Total height.[1]	Merchantable length.	Average top diameter inside bark.	Basis number of trees.
Inches.	*Feet.*	*Feet.*	*Inches.*	*No.*	*Inches.*	*Feet.*	*Feet.*	*Inches.*	*No.*
8	48	[2] 23	.....	.....	40	148	120	11	41
10	57	[2] 30	.....	.....	42	152	125	11	43
12	67	[2] 38	.....	.....	44	156	130	12	39
14	77	45	8	1	46	160	134	12	31
16	86	52	8	2	48	164	138	12	43
18	92	58	9	7	50	168	143	12	41
20	98	65	9	28	52	172	147	12	56
22	104	72	9	23	54	175	151	13	36
24	110	78	9	35	56	178	155	13	25
26	116	84	9	35	58	182	159	13	25
28	121	90	10	44	60	185	163	14	28
30	126	95	10	53	62	188	167	14	25
32	131	100	10	50	64	191	170	14	27
34	136	105	10	38					
36	140	110	11	36	Total	.....	.....	.....	852
38	144	115	11	40					

[1] Basis 287 trees.

[2] Extension of curve.

KEY FOR THE IDENTIFICATION OF SUGAR PINE, WESTERN WHITE PINE, AND WHITE PINE WOODS.

The following key for distinguishing the wood of sugar pine from that of the western and eastern white pine is based chiefly upon characteristics visible under the compound microscope, but all available gross characteristics are also included, and it is believed that these will enable the layman to distinguish the three species. The microscopic characteristics will, of course, be useful mainly to technically trained students. The minute characteristics are often so variable that the student may have considerable difficulty unless he takes into account every characteristic cited in the key and make numerous careful measurements. There is also a good deal of variation in the general gross appearance of the wood of these three pines, but those who are thoroughly familiar with their gross characteristics visible in the rough and finished states will be able to distinguish them quite readily.

Pits on the radial walls of the pith-ray cells two, or sometimes one, per tracheid, round, occurring side by side. Pith rays (tangential section) one to twelve, or often sixteen cells in height. Resin canals about 0.13 to 0.16 mm. in diameter. Wood yellowish white, or often very light brown, with rather coarse grain. Resin canals conspicuous, appearing on a smooth longitudinal surface as dark lines. Sugary exudations and resin pockets common. Weighs about 23 pounds per cubic foot.....SUGAR PINE (*Pinus lambertiana*).

Pits on the radial walls of the pith-ray cells one, two, or occasionally three per tracheid, nearly round, and usually placed irregularly. Pith rays (tangential section) one to seven, or sometimes ten, cells in height. Resin canals about 0.13 to 0.15 mm. in diameter. Wood light brown or reddish, with rather fine grain. Resin canals not numerous and slightly less conspicuous than in the one above. No sugary exudation. Weighs about 24.5 pounds per cubic foot.....WESTERN WHITE PINE (*Pinus monticola*).

Pits on the radial walls of the pith-ray cells one, rarely two, per tracheid, large and mostly oblong. Pith rays (tangential section) mostly one to twelve, or sometimes fourteen, cells in height. Resin canals about 0.08 to 0.12 mm. in diameter. Wood cream yellow, or that from very old trees light brown, slightly tinged with red. Resin canals not very conspicuous and no sugary exudations. Weighs about 24 pounds per cubic foot..WHITE PINE (*Pinus strobus*).

GRADES.

Sugar pine lumber is classified into the following grades:

Thick finish:

No. 1 and 2 clear. 1, 1¼, 1½, 2 inch widths.

No. 3 clear. Same dimensions; must contain 70 per cent No. 1 door cuttings of No. 1 shop common sizes.

C select. Same dimensions, one face finished; admits small defects.

D select. Same as C select, except admits more serious defects.

Siding:

1 and 2 grade (B and better). Thickness ½ inch.

No. 3 siding. Thickness ½ inch; admits greater defects than 1 and 2.

Factory plank or shop common, graded for door cuttings:

No. 1 shop common. From 50 to 70 per cent No. 1 cuttings.

No. 2 shop common. Either 25 per cent No. 1 door cuttings or 40 per cent No. 1 and 2 combined, or 50 per cent No. 2.

No. 3 shop common. 1¼ inch and thicker; not less than 12½ per cent No. 1 and 2 sash and door cuttings.

Inch shop common. Must contain 50 per cent above described cuttings; cuttings must be 10 inches wide or wider, 22 inches long or longer; or, 8 inches wide or wider and 3 feet long or longer.

No. 1 fencing D and M. Sound No. 1 fencing worked to flooring; when worked should be of character of No. 1 common strips.

No. 2 fencing D and M. No. 2 fencing worked to flooring of character No. 2 common strips.

No. 3 fencing D and M. No. 3 fencing worked to flooring; some coarse knots, split and wane.

Common lumber; 1 inch thickness:

No. 1 common boards and strips. Sound, tight-knotted stock, free from large, coarse knots.

No. 2 common. Admits coarser and larger knots and more stained sap.

No. 3 common. Admits large, loose, unsound knots; shake, red rot, blue sap stain.

Thick common lumber, 1¼ inches thick and thicker:

Tank stock. Dimension sizes, free from wane; sound knots and white sap admitted.

Step plank. 8 inches wide or wider; graded the same as No. 1 common boards.

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